STREPTANTHUS MORRISONII COMPLEX

Streptanthus morrisonii complex

FINAL REPORT

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Status Recommendations

Streptanthus morrisonii and *S. brachiatus* are both currently Category 2 candidate species (*Federal Register*, v. 50, No. 188, September 27, 1985). No subspecies are recognized.

The following definitions were used for the status categories (from *Federal Register*, v. 50, No. 188, September 27, 1985):

Endangered: "Endangered species" means a species that is in danger of extinction throughout all or a significant portion of its range.

Threatened: "Threatened species" means any species that is likely to become an Endangered species within the foreseeable future throughout all or a significant portion of its range.

Category 1 - Taxa for which the Service currently has on file substantial information on biological vulnerability and threat(s) to support the appropriateness of proposing to list them as endangered or threatened species.

Category 2 - Taxa for which information now in possession of the Service indicates that proposing to list them as endangered or threatened species is possibly appropriate, but for which substantial data on biological vulnerability and threat(s) are not currently known or on file to support the immediate preparation of rules.

The recommendations for establishing a federal status for each taxon within the *Streptanthus morrisonii* complex were reviewed using the following FWS criteria (from *Federal Register*, v. 48, No. 153, August 8, 1983):

424.11 Factors for listing, reclassifying, or delisting species.

c) A species shall be listed or reclassified if the Secretary determines, on the basis of the best scientific and commercial data available after conducting a review of the species' status, that the species is Endangered or Threatened because of any one or a combination of the following factors:

1) The present or threatened destruction, modification, or curtailment of its habitat and range;

2) Overutilization for commercial, recreational, scientific, or educational purposes;

3) Disease or predation;

4) The inadequacy of existing regulatory mechanisms, or,

5) Other natural or manmade factors affecting its continued existence.

These FWS criteria were used for determinations of Critical Habitat:

424.12 Criteria for designating Critical Habitat

(a) Critical Habitat shall be specified to the maximum extent prudent and determinable at the time a species is proposed for listing. If designation of Critical Habitat is not prudent or if Critical Habitat is not determinable, the reasons for failure to designate Critical Habitat will be stated in the publication of proposed and final rules listing a species.

(1) A designation of Critical Habitat is not prudent when i) The species is threatened by taking or other human activity, and identification of Critical Habitat can be expected to increase the degree of such threat to the species, or ii) Such designation of Critical Habitat would not be beneficial to the species.

Summary of area, numbers, & ownership

These figures were used by Tierra Madre Consultants when making the status recommendations.

Taxon	Area	Numbers	Ownership
Streptanthus morrisonii morrisonii	10 barrens 912 acres	10,000	50% public 50% private
Streptanthus morrisonii hirtiflorus	1 barren 1 acre	10	Private
Streptanthus brachiatus	4 sites 20 acres	1,000	90% private 10% public
Streptanthus brachiatus hoffmanii	11 barrens 230 acres	10,000	65% public 35% private
Streptanthus morrisonii elatus	2 barrens 112 acres	2,000	Public
Streptanthus morrisonii kruckebergii	25 barrens 120 acres	100,000	Public

Recommendations and Justification:

The status recommendations are followed by a discussion of the listing factors which apply to each taxon. Designations of Critical Habitat are not recommended for any taxon of the Streptanthus morrisonii complex because they would not be likely to offer any additional benefit to the species.

Streptanthus morrisonii F. W. Hoffman
ssp. morrisonii F. W. Hoffman

Morrison's jewelflower

CATEGORY 2 CANDIDATE

This plant has a restricted range and habitat and is naturally rare, but substantial data on biological vulnerability and threat(s) are not known. There is no evidence that the taxon is in danger of extinction or likely to become in danger of extinction throughout all or a significant portion of its range.

Factors:

1) Mining is a potential threat. However, the Sonoma County Assessor stated that no valid mining claims are present within the range of this taxon. No other obvious current threats.

2) Application of this factor is unknown at this time.

3) Flower predation by beetles is considerable, but the population does not appear to be threatened by this factor.

4) The Bureau of Land Management owns a significant portion of the habitat of this taxon. This isolated holding is planned for disposal, which would limit the ability of the federal government to protect the species. Local regulatory land use mechanisms may or may not be adequate to protect existing populations.

5) Application of this factor is unknown at this time.

Streptanthus morrisonii F. W. Hoffman
ssp. hirtiflorus F. W. Hoffman

Woolly jewelflower

ENDANGERED

The woolly jewelflower occupies a single site in low numbers and could be eliminated by chance occurrence of a variety of manmade or natural perterbations of its environment. This taxon may always be in danger of extinction because of its natural rarity.

Factors:

1) No current threats observed. Possible future threats unknown.

2) Overutilization for scientific or educational purposes could be a future threat. Application of this factor is unknown at this time.

3) Beetles were observed on some of the flowering adults, but this predation did not appear to hinder seed set in 1986. The small population size could make this taxon vunerable from an increase in predation by flower beetles or browsing by rabbits and deer.

4) Local regulatory land use mechanisms may or may not be adequate to protect existing populations.

5) Due to the extremely small population size at the single known location, this taxon is at risk of extinction from stochastic processes.

Streptanthus brachiatus F. W. Hoffman
ssp. brachiatus

Socrates Mine jewelflower

THREATENED

Because of past losses of habitat and the disturbed nature of the remaining barrens, the Socrates Mine jewelflower is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range. The additional protection of the Endangered Species Act has a high potential to benefit the species.

Factors:

1) A large percentage of the historic habitat of this taxon has been destroyed by mining. The entire geographic range is leased for geothermal development by the federal government and private owners. Existing electrical transmission lines, access roads, and one inactive well are the only developed facilities at this time. The habitat receives use by off-road vehicles, which compact the soil and destroy individual plants. Rock collecting activity has resulted in habitat alteration and loss of individual plants. Maintenance of existing electrical transmission lines could result in the loss of many plants.

2) Overutilization for scientific or educational purposes could be a future threat. Application of this factor is unknown at this time.

3) The plants are subject to predation by deer, rabbits, and flower beetles, which limit seed production.

4) The BLM has permitting authority over the federal mineral rights which underlie some populations. The majority of the habitat is covered by geothermal lease restrictions, conditions, and mitigation measures, which may be adequate. Local regulatory land use mechanisms may or may not be adequate to protect existing populations.

5) Application of this factor is unknown at this time.

Streptanthus brachiatus F. W. Hoffman
ssp. hoffmanii Dolan & LaPre

Hoffman's jewelflower

THREATENED

Because of extensive development within a major portion of its range, the fragmented occurrences, and past losses of habitat and disturbance to barrens habitat, Hoffman's jewelflower is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range. The additional protection of the Endangered Species Act has potential to benefit the species.

Factors:

1) The barrens containing this polymorphic taxon are within a geothermal development area. Existing energy development has generally avoided the barrens habitat. The populations may be subject to cumulative impacts of continuing development activity on the periphery of the barrens. Threats on private lands outside the geothermal development area are unknown.

2) Application of this factor is unknown at this time.

3) The plants are subject to predation by deer, rabbits, and flower beetles, which limit seed production at some sites.

4) The majority of the populations are governed by geothermal lease restrictions, conditions, and mitigation measures, which may be adequate. Local regulatory land use mechanisms may or may not be adequate to protect existing populations.

5) Application of this factor is unknown at this time.

Streptanthus morrisonii F. W. Hoffman
ssp. elatus F. W. Hoffman

Tall jewelflower

THREATENED

Because of it single occurrence, past losses of habitat, and the disturbed nature of the remaining barrens, the tall jewelflower is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range. The additional protection of the Endangered Species Act has a high potential to benefit the species.

Factors:

1) The barrens have suffered considerable degradation from mining and road construction in the past. The land is available for mining claims. Off-road vehicle use is a minor current threat and potential future threat. Grazing by cattle may have eliminated plants at some isolated sites.

2) Application of this factor is unknown at this time.

3) Extensive browsing by deer and rabbits was observed. A small number of plants were crippled by aphids. Flower beetles were abundant in all three years. The population does not appear to be severely limited in seed set by these animals.

4) The BLM has the ability to protect the habitat, which is all on federal land, by establishment of an Area of Critical Environmental Concern, Botanical Area, or Research Natural Area. Establishment of one of these land use designations would provide adequate regulatory mechanisms to protect the taxon..

5) The taxon is very limited in area and numbers, making it vulnerable to environmental perturbations.

Streptanthus morrisonii F. W. Hoffman
ssp. kruckebergii Dolan & LaPre

Kruckeberg's jewelflower

CATEGORY 2 CANDIDATE

This plant has a restricted range and habitat and is naturally rare, but substantial data on biological vulnerability and threat(s) are not known. There is no current evidence that the taxon is in danger of extinction or likely to become in danger of extinction throughout all or a significant portion of its range.

Factors:

1) The majority of the serpentine barrens are within active mining claims which are not in porduction. Off-road vehicle use has caused small losses of plants. Cattle grazing has caused minor disturbances to barrens habitat.

2) Application of this factor is unknown at this time.

3) Flower beetles and seed predators were observed, but neither appeared to limit the population.

4) Existing regulatory mechanisms appear to be adequate. The BLM has included protection of the majority of the populations in its Recreation Management Plan for the Knoxville area. Regulations to protect the populations from future mining may not be adequate.

5) Application of this factor is unknown at this time.

Management

Many factors enter into the management of lands with populations of the rare Streptanthus morrisonii complex members. In most areas development pressure, i.e. new requests for surface-disturbing activities which would negatively impact the populations, is low. Many projects may be compatible with preservation of serpentine barrens habitat, and compatibility with future land uses will be judged by the governing jurisdiction on a case-by-case basis.

This section presents management considerations, some of which are speculative. These are based on observations from the field work or ideas presented in the literature.

A suggested management prescription for each taxon within the Streptanthus morrisonii complex follows the general management discussion. Preservation of all populations of the taxa recommended for threatened or endangered status was assumed to be an overall objective for management.

These recommendations are general and might apply to all managing agencies. The management agencies with jurisdiction over the lands will vary with their ability or desire to implement protective measures. The Bureau of Land Management is the sole manager of lands with S. m. elatus and S. m. kruckebergii populations and a major landowner at other sites. Other agencies which play a role in land management of habitat for the Streptanthus morrisonii complex are the counties of Sonoma, Lake, and Napa, the California Division of Forestry, California Department of Fish and Game, California Energy Commission, and the U. S. Fish & Wildlife Service.

Management Considerations

1. Taxa of the Streptanthus morrisonii complex provide a complicated example of speciation. Some taxa show local differentiation of populations due to isolation of the barrens habitat. The complex is of high scientific importance for studies of genetics and evolution.

2. There are few existing parks or preserves for serpentine barrens. None exist for the protection of any member of the Streptanthus morrisonii complex.

3. The minimum viable population size and the minimum viable preserve size, two important measures in the field of conservation biology, have not been determined for these species. Because of this lack of information, the conservative approach with the objective of preservation of all of the existing undisturbed populations is taken for those species that are recommended for threatened status.

Management considerations (cont).

4. The isolated populations on the barrens may have some biological dependence on the surrounding vegetation. For example, intervening chaparral may support pollinators of the Streptanthus morrisonii complex. Populations could require undisturbed linkages between barrens for genetic interchange. No current scientific evidence is available on this topic. Additional studies of pollinators would be beneficial.

5. Fire may provide increased growth conditions over time and be an essential force in Streptanthus ecology and evolution. The majority of the existing habitat is surrounded by fire-adapted chaparral. One possible scenario is that a large fire might open up habitat for a period of a few years. During this period, the numbers of Streptanthus may increase, along with many species of annuals that prefer open conditions. The increased annual flora following fires attracts more pollinators, conceivably increasing the potential for cross pollination between previously isolated serpentine barrens. No publications are available which discuss the role of fire on Streptanthus morrisonii or S. brachiatus populations.

6. The barrens may undergo a process of succession. Opportunities exist to manage large ecological units where geological processes involved in barrens formation and degradation can be studied in an undisturbed state. Long term habitat changes for Streptanthus morrisonii could be observed. Designation of an undisturbed watershed as a Research Natural Area for study of geological and botanical phenomona might be possible at the Cedars or Knoxville.

7. Other rare plants, including Eriogonum nervulosum and Asclepias solanoana, are found on serpentine barrens with members of the Streptanthus morrisonii complex. Protective management of threatened Streptanthus populations will have the additional benefit of protecting these other rare plants. An unidentified annual Streptanthus is present at Three Peaks and the Cedars. This plant may be a new species or a significant range extension of Streptanthus batrachopus.

8. The populations appear to fluctuate greatly in numbers from year to year and from place to place within the barrens. The plants are difficult to see and count.

9. Any species that is listed as threatened or endangered will require additional regulatory review when any major land-disturbing activities that will result in a loss of many individuals are proposed, including Section 7 consultations with the FWS.

Based on the management considerations, the following objectives are recommended:

Objectives

1. No decrease in existing population size or numbers for those taxa designated as threatened or endangered.
2. Prevent fragmentation of habitat within barrens.
3. Provide sufficient buffer areas around barrens which may insure the biological integrity of the system and occasional genetic interchange.
4. Monitor population numbers and threats for taxa with a single occurrence (S. m. hirtiflorus and S. m. elatus).
5. Consolidate public lands in areas where populations are threatened on private lands or where more efficient management can be achieved.
6. Manage to make the listing of the rare taxa unnecessary.
7. The BLM should acquire access to the barrens at the Cedars and Three Peaks.

Recommended management directives for achieving the stated objectives are presented below:

Implementation

1. Prohibit grading of a natural surface of serpentine rock. Roads must avoid serpentine outcrops containing threatened members of the Streptanthus morrisonii complex.
2. Prescribed burning programs should include serpentine barrens within the burn areas rather than using them as edges. Because the barrens are the most open areas, they are susceptible to damage from vehicles and equipment, and precautions must be taken to avoid surface disturbance. Chaining of vegetation may impact scattered populations, especially near Socrates Mine. Development within the range of a threatened taxon should be compatible with a program for prescribed burns, since fire may be a part of the natural regime of the Streptanthus morrisonii complex.
3. Restore disturbed habitat to more pristine conditions. Limit compaction of soil.
4. Rehabilitate mining scars to re-create the natural contour and surface.
5. Monitor population numbers.
6. Prepare detailed plans for each taxon or barren as necessary. Those species which are currently threatened and in decline may require active management programs in order to reverse their decline.

Management Recommendations for Each Taxon

Streptanthus morrisonii morrisonii

Retain and consolidate public lands containing serpentine barrens. Retention in Category 2 status is dependent on preservation of existing populations on public lands, which constitute about half of the existing barrens habitat. If the land status changes to private from surplus land sales by the BLM, a Threatened status might be more appropriate. Apply watershed approach, acquiring barrens and intervening chaparral and woodland vegetation within a single watershed, so that lands can be managed more easily for fire and erosion control. The Cedars area could be a good place to establish a Research Natural Area. This is because the lands are virtually pristine, without development within the watershed of upper East Austin Creek. Landslides continue to occur after heavy rainfall, and other erosional processes associated with serpentine barrens formation and decomposition take place without human disturbance. The site is one where medium and long term geological processes can be studied along with botanical investigations of the serpentine flora. Distributional questions about size movements of populations within and between barrens over time can be studied in an undisturbed setting, where the lands between the barrens are not fragmented by development, as they are at other sites with Streptanthus morrisonii complex members. The public lands might be linked by acquisition of lands or an access easement to Austin Creek State Recreational Area.

Proposed developments on private lands with serpentine outcrops should be required to perform botanical surveys directed to the serpentine flora, especially the Streptanthus, since an unidentified annual is present, and additional information about S. morrisonii is needed.

Streptanthus morrisonii hirtiflorus

Acquire if the existing population becomes threatened. This plant is an ideal candidate for the Nature Conservancy landowner protection program if the land remains in private hands.

Botanical surveys should be required for land development proposals on private or public lands near this location.

Monitor population numbers.

Streptanthus brachiatus

Prepare a detailed management plan for the Socrates Mine area, including restoration and rehabilitation. Acquisition of surface or mineral rights by the federal government may improve the ability to implement habitat enhancement measures. Advise utilities and geothermal developers of locations at Socrates Mine. Advise Sonoma County of sensitivity of lands in the historic range. Prescribed burns along the ridge between Socrates Mine and Mercuryville may increase available habitat.

Management recommendations for each taxon (cont).

Require future geothermal development to avoid surface disturbance at existing populations. A Memorandum of Understanding between the BLM and Unocal on future management may improve planning for habitat protection at Socrates Mine. Continue to monitor population numbers at all sites.

Streptanthus brachiatus hoffmanii

The populations of this taxon are naturally isolated from each other and occur on eleven serpentine barrens and several other small discrete serpentine outcrops. Preserve habitat and all remaining populations within the geothermal development area. Sites outside the development area on private lands should be reviewed for compatibility with preservation of barrens habitat. Continue monitoring population numbers.

Review fire management plans to assure that prescribed burn operations or other vegetation manipulation (e.g. brush clearing) do not adversely impact populations. Occasional fire may be beneficial.

Investigate insect predation and pollinators.

Streptanthus morrisonii elatus

Restrict uses to those compatible with preservation of barrens habitat. A reclamation/restoration plan which eliminates some road cuts and mining scars would be desirable. Active management may be needed to increase the population size. The BLM should designate this area as an ACEC (Area of Critical Environmental Concern) or Botanical Area. Continue to monitor population numbers, including the unidentified annual Streptanthus. Obtain access by acquisition or easement over the private parcel at White Point.

Streptanthus morrisonii kruckebergii

Restrict uses to those compatible with preservation of the barrens habitat. Retention in Category 2 status is dependent on preserving existing populations. A change to Threatened might be necessary if incompatible uses, such as surface mining on the barrens, are allowed. Monitor threats to the barrens from expanded off-road vehicle use to see if the Recreation Management Plan for the Knoxville area is effective.

Many of the Knoxville populations occur on remote barrens where no disturbance is taking place within the entire watersheds, as on some of the tributaries of Hunting Creek. Designation as a Research Natural Area or Botanical Area is possible for these undisturbed regions within the Knoxville Recreation Area.

SCIENTIFIC
PUBLICATIONS

STREPTANTHUS MORRISONII COMPLEX

An Electrophoretic and Morphological Re-examination of the Rare Serpentine Endemic *Streptanthus morrisonii* Complex (Brassicaceae)[1,2]

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[2]To be submitted to *American Journal of Botany*.

ABSTRACT

Recent exploration for geothermal development in Lake, Napa, and Sonoma Counties, CA, has led to the discovery of several previously undescribed taxa in the *Streptanthus morrisonii* complex. Because these rare serpentine endemics show high levels of local differentiation, taxonomic assignments in the genus can be problematic. This study uses data from starch gel electrophoresis, morphological analysis, and geographical distribution to assess the adequacy of the existing taxonomy in the complex and to assign names to the newly discovered populations. All taxa studied are closely related genetically, based on enzyme variants (overall mean genetic identity for pairwise comparisons of all sites is 0.874). Alleles in the PGM3 locus delineate species. Morphological data support assignments based on these genetic studies. Although the original classification of the four-taxon complex is supported by these new data, two new subspecies were identified. This first application of electrophoretic analysis of enzyme variants to the taxonomy of *Streptanthus* demonstrates that the technique can be useful in determining an appropriate specific and infraspecific classification for a polymorphic genus.

INTRODUCTION

Many endemic plants occur in Lake, Napa, and Sonoma counties of California, within the Central Coast Ranges (Stebbins and Major, 1965). Serpentine rock provides habitat for some of these endemics. This essentially unweathered, friable substrate offers a seemingly hostile environment for most plants: little soil, high temperature and moisture stress, heavy metals (such as nickel, chromium, and lead), and low levels of essential nutrients (Kruckeberg, 1984). Nonetheless, an estimated 27 species are endemic to serpentine from this region in California (Kruckeberg, 1984).

Because recent geothermal development in "The Geysers" area of southern Lake County has included resources below serpentine outcrops, these areas have experienced increased access and floristic exploration. Several apparently distinct taxa, previously undescribed, that appear to be "biennials" (i.e. monocarpic perennials) in the genus *Streptanthus* have been discovered (Neilson, 1977).

Strepthanthus, the subject of classic studies on the nature of edaphic specialization and evolution (Kruckeberg, 1950; 1954; 1967), exhibits much local differentiation due to the discontinuity of the serpentine habit to which many of its species are restricted (Kruckeberg, 1956, 1958). *Strepthanthus brachiatus* F. W. Hoffman (Socrates Mine jewelflower) and *S. morrisonii* F. W. Hoffman (Morrison's jewelflower), the only biennials in the genus (other species are strict annuals or perennials), have rarely been collected and are poorly studied. Not described until 1952 (Hoffman, 1952), *S. brachiatus* and two of three subspecies of *S. morrisonii* are of extremely limited distribution. Both species are candidates for listing under the Endangered Species Act (Federal Register, Vol. 50, No. 188, Friday, Sept. 27, 1985).

The objective of my study was to assess the existing classification of the biennial *Streptanthus* (section *Biennes* [Kruckeberg and Morrison, 1983]) and to determine the status of newly discovered populations. Because morphological diversity makes taxonomic assignments difficult in this genus, biochemical data from starch gel electrophoresis was evaluated, along with more data from traditional morphological analysis and distributional data, to determine affinities within the section.

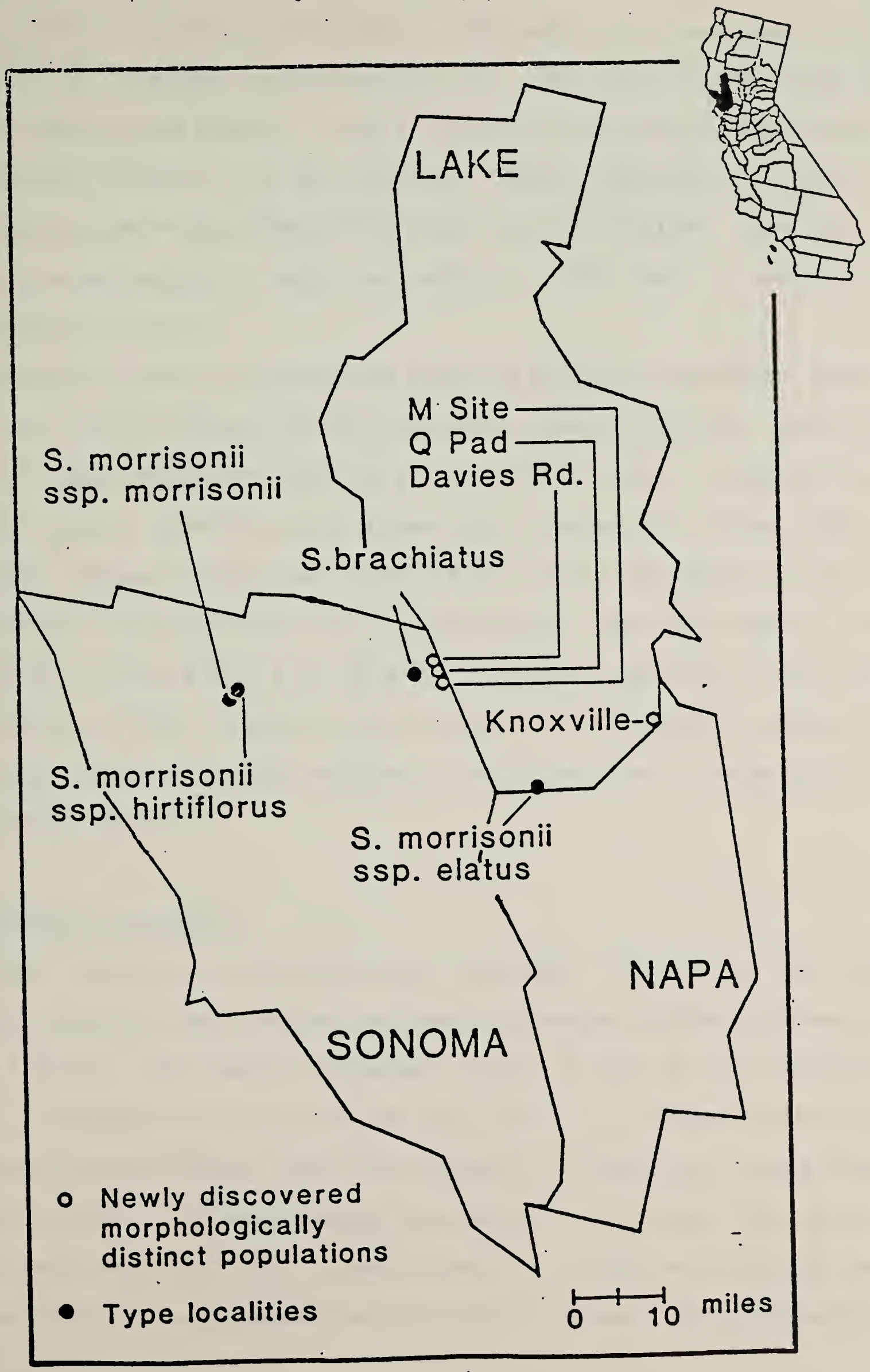
MATERIALS AND METHODS

Taxa, distributions, and collection sites

Members of the *Streptanthus morrisonii* complex are distinguished from other species in the genus by their loose biennial life history and associated glabrous, glaucous, entire, cabbage-like rosette leaves (Hoffman, 1952). *Streptanthus brachiatus* is a morphologically uniform, monotypic species that has been collected only from the immediate vicinity of Socrates Mine in the Mayacmas Mountains of northern Sonoma County (Fig. 1). The habitat has been largely destroyed by past mining. Plants occur primarily on open outcrop surfaces but are also found scattered in adjacent chaparral.

As presently constituted, *Streptanthus morrisonii* has been divided into three subspecies. *S. morrisonii* ssp. *morrisonii* grows on serpentine outcrops and adjacent serpentine chapparral in central Sonoma County. This subspecies, the most widely distributed taxon in the complex, grows in the large serpentine area known as "The Cedars" (Fig. 1). Within the range of *S. morrisonii* ssp. *morrisonii* is *S. Morrisonii* ssp. *hirtiflorus*, a highly restricted taxon known from only one outcrop in an area 100 m2 and totalling only several

Figure 1. Map of the type localities and collection sites of the *Streptanthus morrisonii* complex and newly discovered populations.



hundred plants. Disjunct to the east of The Cedars is *S. morrisonii* spp. *elatus*, on the Lake–Napa county line (Fig. 1). This taxon is restricted to several closely spaced outcrops. None of these taxa has been collected beyond the immediate vicinity of its type locality. Table 1 summarizes the significant features upon which Hoffman (1952) based his classification. Type localities, estimated geographic ranges, and numbers of individuals for each taxon are presented in Table 2.

Recent collections of *Streptanthus* from "The Geysers" (Lake-Sonoma county line) and from the extreme eastern Lake–Napa county line near Knoxville (Figure 1) share distinctive features of the section *Biennes*: cabbage–like, glabrous, glaucous juvenile rosette leaves and a biennial life history (Hoffman, 1952). However, these populations are not clearly assignable to any of the described taxa and are not within the previously described range of any taxon in the section (Table 1 or Table 2). Moreover, populations identified as Davies Road, Q–Pad, and M–site occur on single outcrops within 1,000 km of each other. Despite this close association, each population is morphologically uniform and distinct.

Electrophoretic procedures

Single flowering inflorescences were collected in the field for each previously described taxon and the four newly discovered entities described in Tables 1 and 2. Abbreviations presented in Table 2 refer to the collection sites. For these restricted taxa, the type locality is frequently the only site where the taxon grows. Note that population and taxon are in many cases equivalent terms. For *Strepthanthus brachiatus, S. morrisonii* ssp. *hirtiflorus,* and *S. morrisonii* ssp. *elatus*, material for study was collected from the type locality. *Strepthanthus morrisonii* ssp. *morrisonii* was collected at

Table 1. Distinguishing features of the *Streptanthus morrisonii* complex, described taxa, and related, newly discovered populations.

Taxon	Morphological traits				
	Calyx color	Calyx pubescence	Juvenile leaf color	Upper connate filaments	Habit
S. brachiatus (SB)	purple	absent	mottled	w/purple vascular traces	short, much branched
S. morrisonii (MM) ssp. *morrisonii*	yellow	most glabrous	uniformly green	w/orange vascular traces	tall, remotely branched
S. morrisonii (MH) ssp. *hirtiflorus*	purple	hirtellous	mottled	w/purple vascular traces	intermediate height, variable branching
S. morrisonii (ME) ssp. *elatus*	yellow	variable	heavily mottled w/purple-brown	uniformly yellow	tall, remotely branched
Population (abbreviation)					
Davies Rd (DR)	purple	variable	mottled	w/purple vascular traces	short, much branched
Q-Pad (QP)	yellow or purple	variable	mottled	w/purple vascular traces	short, much branched
M-Site (MS)	yellow	variable	mottled	w/purple vascular traces	intermediate, remotely branched
Knoxville (KX)	yellow	variable	mottled	uniformly yellow	tall, remotely branched

Table 2. Distribution and estimated numbers of individuals for described taxa and newly discovered populations in the *Streptanthus morrisonii* complex.

Taxon (abbreviation)	Estimated no. of individuals	Distribution
S. brachiatus (SB)	1,000	Type locality: exposed Serpentine Ridge near Socrates Mine (now believed to have been incorrectly identifed by Hoffman as Contact Mine), east of Pine Flat, Sonoma county, California, on the Sonoma-Lake county line, elevation 3,000 ft. Range: immediate vicinity of Socrates Mine.
S. morrisonii ssp. morrisonii (MM)	10,000	Type locality: serpentine outcrop, head-waters of Big Austin Creek at Layton Chromite Mine, Sonoma county, California. Range: additional sites in "The Cedars," Red Slide on Bargemann Creek, Devil Creek, Gilliam Creek—all tributaries of East Austin Creek and located in the same serpentine area.
S. morrisonii ssp. hirtiflorus (MH)	100–200	Type locality: headwaters of East Austin Creek, a short distance above Dorrs' Cabin, Sonoma county, California. Range: found only at this site, in an area of 100 m^2.
S. morrisonii ssp elatus (ME)	1,000–2,000	Type locality: serpentine outcrop low saddle, 0.25 mi. west of White's Point, Table Mountain Road, ca. 5 mi. east of Mountain Mill House, Napa-Lake county line, California. Range: known only from this location.

Table 2 (continued)

Population (abbreviation)	Estimated no. of individuals	Distribution
Davies Rd (DR)	1,000	Known only from a few adjacent serpentine outcrops near the intersection of Ridge Road and Davies Road on the Lake-Sonoma county line.
Q-Pad (QP)	1,000	Known only from a few adjacent outcrops between Davies Road and Bear Ridge Road in Lake county, just north of the Sonoma county line (southeast of above).
M-Site (MS)	1,000–2,000	Scattered outcrops just southeast of the above sites and northwest of Mt. St. Helena in Napa county near Buck Rock.
Knoxville (KX)	100,000	Scattered outcrops near Dunnigan Hill on the Lake-Napa county line in the region of Knoxville.

Red Slide in The Cedars north of Austin Creek State Park in Sonoma County. DR was collected off Davies Road 0.5 mi. from junction with Bear Ridge Road, Lake County. QP was collected at Q-Pad, and MS was collected at M-lease site in the geothermal development area, on Bear Ridge Road in Lake County. KX was collected on Dunnigan Hill in Lake county near Knoxville.

Material from 10-15 plants was collected per location. I believe that a sufficient sample of biochemical and morphological variation could be obtained from this small sample size, while causing little impact to these rare taxa. For the extremely rare *Streptanthus morrisonii* spp. *hirtiflorus*, only two plants were tested. As a result, this taxon was not included in analyses of genetic data. Flowers and buds were wrapped in paper towels, placed in plastic bags, and shipped within 24 hr. to Butler University, where they were processed for horizontal starch gel electrophoresis. Material collected, shipped in this way, and refrigerated upon arrival, remained viable for up to 10 days. Although flower buds proved to be the best material, leaves from greenhouse-grown plants were also assayed to resolve troublesome systems. Not all enzymes active in flowers are active in leaves, however.

Tissue was extracted in a buffer of 25 ml tris pH 8.0, 25 ml distilled water, and 77 mg dithiothreitol. Alcohol dehydrogenase (ADH) and phosphoisomerase (PGI) were run in a variation of the Poulik buffer system (Heywood, 1980) at 200 mv for 2.5 hr. Malate dehydrogenase (MDH) and phosphoglucomutase (PGM) were run in a histidine/citrite buffer system (Ellstrand, 1984) at 25 ma for 3 hr. Esterase (EST) was run in a lithium borate system (Scandalios, 1969) at 200 mv for 2.5 hr. Standard enzyme stains were used (Shaw and Prasad, 1970; Soltis et al., 1983), except for ADH, for which the staining solution was buffered with tris at pH 8.5. When more than one locus was observed for an enzyme, loci were numbered sequentially, with the least

anodally migrating locus designated 1. Enzyme variant for individual loci were assigned sequential letters in the same manner.

Morphological Studies

Ten arbitrarily chosen individuals were measured from each study population, excluding the extremely rare taxon, *S. morrisonii hirtiflorus*. Fresh material was used for scoring, except in the case of floral measurements, which were conducted on flowers preserved in 70 % ethanol. Salient diagnostic characteristics do not preserve well in herbarium specimens. Fifteen traits were scored, including pubescence (ranging from 0 for glabrous to 3 for dense pubescence), presence of rosette mottling, calyx color, presence of dark vascular traces on the upper connate filaments, length/width ratio of lower inflorescence leaves, and a series of metric floral traits (Table 3). These selected traits distinguish the previously described taxa in the complex (Hoffman, 1952). However, the number of inflorescence branches, in general an important distinguishing feature, was not scored because it varies greatly with phenology in these indeterminately flowering plants.

RESULTS AND DISCUSSION

Scorable, clear, highly resolved banding was obtained for nine loci from a total of five enzymes: ADH-1 locus, EST-1 locus, MDH-2 loci, PGI-2 loci, PGM-3 loci. MDH and PGI were monomorphic with the same alleles for all popu-

Table 3. Morphological differences among taxa of *Streptanthus brachiatus* and *S. morrisonii* and proported related populations. Values recorded are means and standard deviations (n = 10). Ranges of the characters are shown in parenthesis. See text for taxon and location descriptions.

Trait	Taxon or population						
	MM	ME	SB	DR	QP	MS	KX
Calyx pubescence (0–3)	0.1±0.3 (0-1)	0.3±0.5 (0-1)	0.0±0	1.9±0.3 (1-2)	1.0±0.7 (0-2)	0.7±1.1 (0-3)	1.7±0.5 (1-2)
Flower length (mm)	9.9±1.7 (8-11)	9.3±0.9 (7-10)	7.6±0.7 (7-9)	7.8±0.9 (7-9)	7.9±0.9 (7-9)	7.4±0.7 (6-8)	9.1±0.7 (8-10)
Calyx length (mm)	8.4±1.1 (7-11)	7.3±0.9 (7-8)	6.9±1.3 (6-9)	6.6±0.7 (6-8)	6.80.6 (6-8)	6.3±0.5 (6-7)	7.5±0.5 (7-8)
Petal length (mm)	9.5±0.7 (8-10)	8.1±0.9 (7-9)	7.7±1.0 (7-9)	8.4±0.7 (7-9)	8.4±0.7 (7-9)	8.0±1.1 (6-8)	9.1±0.7 (8-10)
Upper stamen length (mm)	8.5±1.9 (7-13)	8.2±1.1 (7-10)	8.2±0.9 (7-10)	8.8±0.8 (8-10)	9.0±0.7 (8-10)	6.8±1.1 (5-9)	8.6±1.1 (8-10)
Lower stamen length (mm)	4.4±1.0 (3-6)	5.4±0.9 (4-7)	6.0±0.9 (5-8)	6.5±0.8 (5-8)	6.6±0.7 (6-8)	3.9±1.0 (2-5)	5.5±0.7 (4-6)
Lower anther length (mm)	2.4±0.5 (2-3)	2.0±0	2.0±0	1.9±0.3 (1-2)	2.0±0.5 (1-3)	1.8±0.6 (1-2)	2.4±0.5 (2-3)
Lateral stamen length (mm)	5.9±1.3 (5-8)	3.8±0.8 (3-5)	4.6±1.0 (4-6)	4.8±0.6 (4-6)	4.9±0.6 (4-6)	5.3±1.0 (4-7)	4.1±0.5 (3-5)
Lateral anther length (mm)	2.1±0.4 (2-3)	2.0±0	2.0±0	2.0±0	2.0±0	2.0±0 (2-3)	2.0±0.5
Rosette mottling present (0 = absent, 1 = present)	0.0±0	0.0±0	1.0±0	1.0±0	1.0±0	0.0±0	0.0±0
Plant height (cm)	41.0±14.1 (22-65)	75.6±20.2 (35-105)	28.3±6.2 (17-37)	20.5±9.1 (7-34)	29.1±3.5 (14-61)	24.7±6.3 (15-32)	69.9±26.2 (20-114)

Table 3 (continued)

Trait	Taxon or population						
	MM	ME	SB	DR	QP	MS	KX
No. of leaf scars	25.2±6.8 (14-40)	26.2±9.6 (10-37)	16.7±4.5 (12-25)	28.8±10.4 (10-46)	32.0±14.7 (8-60)	30.0±12.7 (18-60)	17.0±9.9 (5-38)
Calyx color (0 = yellow, 1 = purple)	0.0±0	0.0±0	1.0±0	1.0±0	0.0±0	0.0±0	0.0±0
Purple vascular traces on upper connate filaments (0 = absent, 1 = present)	0.0±0	0.0±0	1.0±0	1.0±0	1.0±0	1.0±0	0.0±0
Length/width ratio of of lower inflorescence leaves	1.30±0.49 (0.89-2.25)	3.04±1.0 (2.04-3.43)	2.46±0.51 (1.99-3.38)	1.70±0.36 (1.40-2.50)	1.74±0.25 (1.50-2.10)	2.76±0.71 (1.55-3.00)	1.40±0.41 (0.86-1.92)

lations studied. Allele frequencies for variable loci are presented in Table 4. Throughout the study, as fresh material of *Strepthanthus* species from the related sections *Euclisia* and *Hesperides* (Kruckeberg and Morrison, 1983) was encountered, it was scored for the loci as well. These taxa showed banding patterns divergent from those of members of the section *Biennes*.

Locus PGM3 delineates the subspecies of *Streptanthus morrisonii* from *S. brachiatus*. Newly-discovered populations DR, QP, and MS clearly are very similar to the variable *S. brachiatus* for this locus rather than to the monomorphic *S. morrisonii* populations. The PGM2 allele C is also unique to *S. brachiatus*, DR, QP, and MS, and occurs relatively often at these sites. The KX population has a population-specific allele in the PGM1 locus and lacks any banding in the PGM3 locus.

The overall genetic similarity of allele frequencies was calculated using Nei's unbiased genetic identity (1978). Values of genetic identity range from 0 for populations that have no alleles in common, to 1 when populations are genetically uniform. The values for pairwise comparisons of all populations are presented in Table 5. The mean genetic identity for pairwise comparisons of all sites is 0.874.

Gottlieb (1977), using data from numerous electrophoretic and taxonomic studies, concluded that conspecific populations generally have genetic identity values of 0.95 ± 0.02, while closely related species are more differentiated, averaging mean genetic identities of 0.67 ± 0.07. Genetic identity values of the *S. morrisonii* complex support the notion that all the taxa in the complex are closely related despite the local differentiation present. Table 5 shows that *S. morrisonii* ssp. *elatus* and sp. *morrisonii* have a genetic identity of 0.927, thus supporting their classification as conspecific by Hoffman (1952). Both are less similar to *S. brachiatus* (0.831 and 0.886

Table 4. Allele frequencies at polymorphic loci for populations of the *Streptanthus morrisonii* complex (n = 10).

		Population or taxon *							
Gene	Allele	MM	MH**	ME	SB	DR	QP	MS	KX
PGM1	a	.05	—	—	—	—	—	—	—
	b	.95	1.00	1.00	.55	.45	.30	.95	.10
	c	—	—	—	.45	.55	.70	.05	—
	d	—	—	—	—	—	—	—	.90
PGM2	a	.95	1.00	.85	.25	.40	.10	.05	.15
	b	.05	—	.15	.35	.30	.55	.85	.85
	c	—	—	—	.40	.30	.35	.10	—
PGM3	a	1.00	1.00	1.00	.20	.60	.60	.35	—
	b	—	—	—	.50	.10	.20	.35	—
	c	—	—	—	.25	.30	.20	.30	—
	d	—	—	—	.05	—	—	—	—
EST	a	.80	.50	—	.20	.20	.10	.55	—
	b	.20	.50	1.00	.80	.80	.90	.45	.50 ‡
	c	—	—	—	—	—	—	—	.50 ‡
ADH	a	1.00	1.00	1.00	.95	.90	.70	1.00	1.00 ‡
	b	—	—	—	.05	.10	.30	—	—

*Described taxa:
MM = *S. morrisonii* ssp. *morrisonii*
MH = *S. morrisonii* spp. *hirtiflorus*
ME = *S. morrisonii* ssp. *elatus*
SB = *S. brachiatus*

New localities:
DR = Davies Rd.
QP = Q-Pad
MS = M-site
KX = Knoxville

** based on n = 2 for this rare taxon.

‡ based on n = 1.

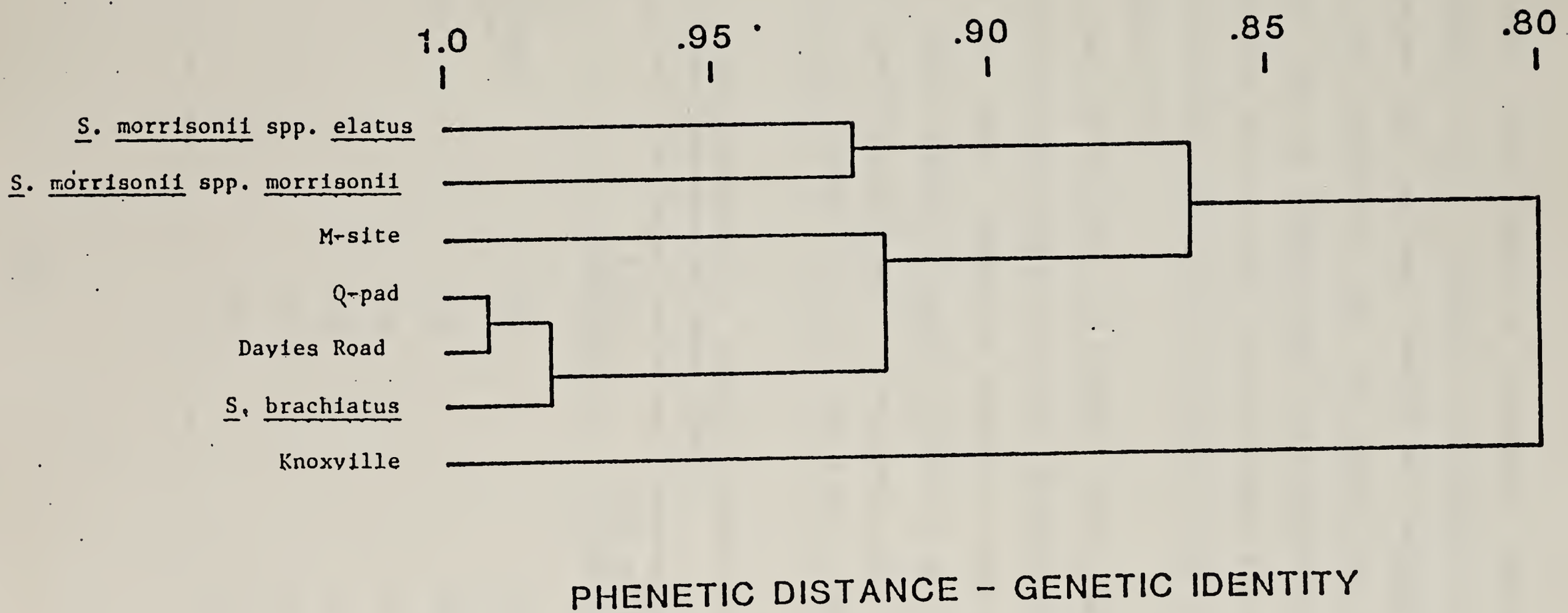
respectively). Table 5 further reveals a high similarity between *S. brachiatus* and three of the newly discovered populations DR, QP, and MS. These high genetic identity values support the assignment of these populations as subspecies of *S. brachiatus*. The Knoxville (KX) population is the most dissimilar of all studied but still shows alleles in common with other members of the complex.

Figure 2 is a cluster diagram (generated by the UPGMA method, Sneath and Sokal, 1973) that graphically summarizes the overall genetic similarity of populations, using the pairwise genetic identity values. The first branch in the dendrogram separates KX from the other sites and taxa, indicating that KX is the most genetically distinct. The second branch separates the *Streptanthus morrisonii* subspecies from *S. brachiatus* and the newly discovered populations MS, QP, and DR. These sites clearly cluster with *S. brachiatus*. The DR and QP sites are more similar genetically to *S. brachiatus* than the subspecies of *S. morrisonii* are to each other. The MS site clusters with this group but is more divergent.

Table 5. Nei's unbiased genetic identity (Nei, 1978) values for pairwise comparisons of populations of members of the *Streptanthus morrisonii* complex.

	MM	ME	SB	DR	QP	MS
ME	0.927	—	—	—	—	—
SB	0.831	0.886	—	—	—	—
DR	0.883	0.934	0.989	—	—	—
QP	0.790	0.869	0.973	0.993	—	—
MS	0.868	0.861	0.944	0.919	0.896	—
KX	0.701	0.751	0.842	0.829	0.826	0.843

Figure 2. Cluster diagram of Nei's unbiased genetic identity (Nei, 1978) generated by the UPGMA methods (Sneath and Sokol, 1973).



Hoffman's (1952) classification of *Streptanthus morrisonii* and *S. brachiatus* as congenerics and his subspecific designation for *S. morrisonii elatus* and *S. morrisonii* ssp. *morrisonii* (despite their geographic separation) are supported by these biochemical data. The complex as a whole is more similar genetically than the average values for congeneric and conspecific comparisons presented by Gottlieb (1977), but the natural divisions and clusters in the electrophoretic data parallel Hoffman's classification scheme based on morphological traits.

Although the goals of this study are taxonomic and the sample sizes used are small for population-level descriptions, the electrophoretic data provide some evidence of the genetic variability present in these geographically restricted taxa. Overall measures of genetic variability show that *S. brachiatus* is a highly variable species while *S. morrisonii*, with its three described subspecies, is less variable (Table 6). The Knoxville (KX) population

Table 6. Levels of electrophoretically detectable genetic variability in populations of the *Stretanthus morrisonii* complex.

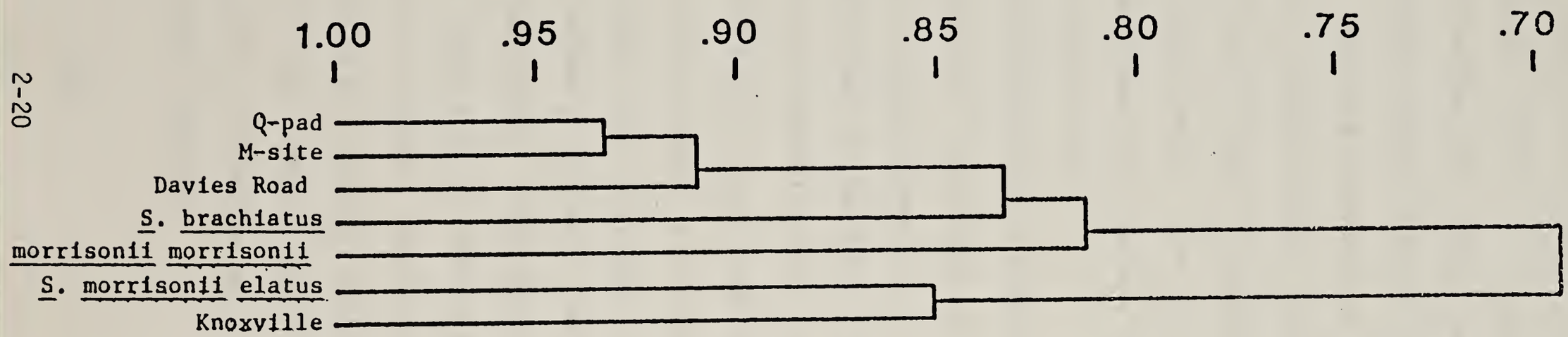
Population or Taxon	% Loci polymorphic	Avg. no. alleles per locus
S. morrisonii		
ssp. *morrisonii*	33.5	1.33
ssp. *elatus*	11.1	1.11
S. brachiatus	55.6	1.89
DR	55.6	1.78
QP	55.6	1.78
MS	44.4	1.67
KX	33.3	1.22

is also much less variable than *S. brachiatus*. Although no accounts of enzyme variation for other *Streptanthus* taxa have been published, Hamrick et al. (1979) have reported an average of 23.52 ± 5.06 percent loci polymorphic and 1.43 ± 0.11 alleles per locus for 17 endemic species, lower than that recorded for narrow, regional, or widespread species. Values for the *S. morrisonii* complex show these taxa are more genetically variable than most endemics (Table 6). Similarly, they are more variable than most biennials for which electrophoretic data have been assimilated (Hamrick et al., 1979).

Values for the morphological traits scored are presented in Table 3. Degree of pubescence, although used as a distinguishing trait by Hoffman (1952), is variable in almost all populations studied. A range of pubescence seems to be the rule for species of *Strepthanthus* (see Kruckeberg, 1958), but its usefulness as an important taxonomic indicator is questionable. Plant habit (tall vs. short) and the presence or absence of darkened vascular traces on the upper pair of connate filaments are traits that best distinguish these groups.

When all traits are considered, cluster analysis of the morphological data (Fig. 3) shows that DR, MS, and QP populations cluster together with SM, the Socrates Mine jewelflower, *Streptanthus brachiatus*. *Streptanthus morrisonii elatus* and the Knoxville population (KX) cluster as a separate group. Curiously, *Streptanthus morrisonii* ssp. *morrisonii* (ME) clusters with the *S. brachiatus* group but is the most dissimilar. The morphological data support the conclusions based on electrophoretic analysis that the newly-discovered populations DR, MS, and QP are more closely related to *Streptanthus brachiatus* than to *S. morrisonii*. On the basis of morphological

Figure 3. Cluster diagram of phenetic distance for 15 morphological traits. Matrix based on similarly (2 w/a+b), tree generated by UPGMA method (Sneath and Sokol, 1973).



PHENETIC DISTANCE - MORPHOLOGICAL TRAITS

characteristics, MS is more similar to members of the complex than indicated by the biochemical analysis. Similarly, the newly discovered KX site shows closer morphological than biochemical affinity to *S. morrisonii elatus*.

Although the population at M-site (MS) shares characteristics with the *Streptanthus brachiatus* group (most notably the dark vascular trace on the upper connate petals), MS calyx color and plant habitat are more similar to *S. morrisonii* ssp. *elatus*. M-site is located nearest the range of *S. morrisonii* ssp. *elatus* and may have originated through introgression of the two taxa, although I have no evidence of hybridization. The low level of electrophoretic variation present in *S. morrisonii* ssp. *elatus* makes it difficult to identify genotypes of potential hybrid origin.

Preliminary greenhouse hybridization studies indicate that DR, QP, and MS are all completely interfertile, as are the subspecies of *S. morrisonii*. No seed set has yet been produced in crosses between any *S. morrisonii* subspecies and *S. brachiatus*. Plants from KX have not yet been induced to flower in synchrony with other sites to allow experimental crosses. Phenology of flowering in the laboratory is very uniform within sites; *Strepthanthus brachiatus*, DR, QP, and MS initiated flowering approximately eight weeks before taxa of *S. morrisonii*. *Streptanthus morrisonii* ssp. *morrisonii* and *hirtiflorus* from western Sonoma County flowered before *S. morrisonii* ssp. *elatus* and KX, collected further east. Similar phenological differences have been observed in the field (LaPré, pers. com.). When sown in uniform potting mixture, calyx color differences characteristic of different populations were still discernable but faded considerably; calyces of greenhouse plants were primarily green with a faint yellowish or purplish hue. Because serpentine can vary in composition over a short distance, edaphic differences may contribute to phenotypic differences observed between adjacent outcrops.

Thus, enzyme similarity, morphological similarity, and preliminary interfertility evidence support the validity of Hoffman's (1952) taxonomic assignments of taxa in the section *Biennes*. *Strepthanthus brachiatus* is distinct from *S. morrisonii*, and the three subspecies of *S. morrisonii* are clearly more related to each other than to their closest relative, *S. brachiatus*. The only previous chemotaxonomic study of *Streptanthus*, based on profiles of glucosinulates (mustard oil glucosides) in seeds (Rodman et al., 1981), found *S. brachiatus* and *S. morrisonii* to be distinct and relatively dissimilar. Infraspecific variation was detected in *S. morrisonii*, corresponding to described subspecies.

Of the four new populations studied, the three in the vicinity of Socrates Mine (DR, QP, and MS) show closest affinity to *S. brachiatus*; they are very similar genetically (Figure 2). However, based on analysis giving equal weight to all morphological traits (Figure 3), *S. brachiatus* as defined by Hoffman (1952) is the most distinct. On this basis it is appropriate to designate the three newly discovered populations as a polymorphic subspecies of *S. brachiatus*. The newly discovered Knoxville (KX) population shows great morphological similarity to *S. morrisonii* ssp. *elatus*, despite its genetic distance. Based on overall variation and differentiation within species, I feel this population should be designated as a distinct subspecies. Detailed taxonomic descriptions will be published elsewhere.

The addition of these intraspecific populations to the known distribution of *Strepthanthus brachiatus* and *S. morrisonii* increases the known geographic distribution of each species, but they are still taxa of limited range with special edaphic requirements. The described subspecies are morphologically and to some extent genetically, unique. Factors that threaten the serpentine outcrop habitat on which all these plants depend will certainly influence

their survival. Although additional populations probably occur on unexplored outcrops in the vicinity, it is likely that neither species will be discovered outside of Lake, Napa, or Sonoma counties.

The significant degree of local morphological differentiation characteristic of the *Streptanthus morrisonii* complex and other species complexes within *Streptanthus* presumably reflects the discontinuous nature of the habitat, the lack of seed dispersal between sites, and variations in the composition of the serpentine substrate. The genetic similarity detected here between morphologically distinct populations parallels genetic observations for the more widely distributed species *Streptanthus glandulosus;* fertility of F_1 hybrids is more influenced by geographic proximity of populations than by subspecific designation based on morphological features (Kruckeberg, 1956). These results imply that similar selective pressures may be operating on populations at different sites, thus discouraging genetic divergence.

Analysis of enzyme variants in members of the *Strepthanthus morrisonii* complex provides a useful technique to aid in assigning relationships within this very polymorphic group. However appealing, it is simplistic to assume that useful taxonomic distinctions at the infraspecific level can be made solely on the basis of objective analysis of biochemical data. For extremely polymorphic taxa for which identification of significant morphological traits is difficult, analysis of enzyme variants is one more piece of evidence on which to base taxonomic assignments. These data are best used in conjunction with standard morphological and hybridization studies.

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TAXONOMY OF *STREPTANTHUS* SECT. *BIENNES*, THE *STREPTANTHUS MORRISONII* Complex (Brassicaceae)

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Abstract

The *Streptanthus morrisonii* complex is a four-taxon group of closely related serpentine rock outcrop endemics. Two new subspecies from Lake County, California, are described. The relationship of these taxa to others in the section is reviewed with descriptions and a key.

Because of expanding geothermal and gold mining operations in Lake, Napa, and Sonoma counties of California, recent floristic surveys of serpentine rock outcrops have revealed new data on many rare and unusual plants. These surveys have discovered previously undescribed populations of plants that are clearly members of the section *Biennes* of the genus *Streptanthus* (*Streptanthus morrisonii* F.W. Hoffman complex), and yet do not match the morphology or geographical distribution of the described taxa (Hoffman 1952). Some *Streptanthus* taxa restricted to serpentine are known for extreme local differentiation that can make nomenclatural assignments problematic (Kruckeberg 1956, 1958). We undertook a study of the biochemistry, morphology, and distribution of the section to evaluate the existing taxonomy and to determine the taxonomic status of newly-discovered populations in the section. Although many of the details of this study have been published elsewhere (Dolan 1987), we present our taxonomic treatment of the complex.

Hoffman first addressed the taxonomy of "biennial" (i.e., monocarpic perennial) *Streptanthus* in 1952. He collected and described two species, one of which had three distinct subspecies. These plants grow on serpentine outcrops of limited access and had not previously been collected. Hoffman placed his taxa in the subgenus *Euclisia* Nutt. ex T & b (*Streptanthus* with zygomorphic flowers, nonbracteate inflorescences, and one or two pairs of stamens with connate or partially connate filaments), monographed by Morrison in 1941. The biennial *Streptanthus* were recognized as section *Biennes* by Kruckeberg and Morrison (1983).

Members of the *Streptanthus morrisonni* complex have glabrous and glaucous vegetative parts. Their most distinctive feature is cabbage-like juvenile rosette leaves that are broad, palmately-lobed, fleshy or succulent, and often mottled on the adaxial surface. Succulent rosette leaves indicate the biennial life history characteristic of the group. Some related *Streptanthus* that grow on serpentine also possess fleshy juvenile leaves. This tendency toward succulence appears to be one of the suite of traits shared by serpertine endemics that has been called the "serpentine syndrome" (Kruckeberg 1984).

The newly-discovered populations are in Lake County, California (Fig. 1). They differ from the described taxa in the complex in their morphological traits (Table 1) and/or geographic range. Plant habit, flower color, and leaf characteristics are the most significant discriminating traits. On the basis of these features, and genetic relationship as revealed by starch gel electrophoresis of enzyme variants (Dolan 1987), our data support the taxonomy of the section as developed by Hoffman (1952) with the addition of two new subspecies: one new subspecies each of *Streptanthus brachiatus* and *S. morrisonii*. The relationship of these subspecies to other members of the complex is presented in the following key.

KEY TO THE SECTION *BIENNES* OF THE GENUS *STREPTANTHUS*

Calyx greenish yellow to golden yellow, occasionally purplish; upper connate filaments without longitudinal colored lines.

Upper and lower surfaces of juvenile and lower leaves usually green; upper connate filaments uniformly orange or orange-yellow; plants endemic to serpentines of Big and East Austin creeks, Sonoma County...1. *S. morrisonii* subsp. *morrisonii*.

Upper surfaces of juvenile and lower leaves heavily mottled with purple-brown, lower surface uniformly purplish; upper connate filaments uniformly yellow.

Plants usually 50-100 cm tall; endemic to serpentines on the headwaters of St. Helena and Bucksnort creeks, Lake County...2. *S. morrisonii* subsp. *elatus*.

Plant usually less than 50 cm tall; endemic to The Cedars/Dunnigan Hill area of eastern of Lake County near the Napa County line...3. *S. morrisonii* subsp. *kruckebergii*

Calyx purple, rose, or yellow, upper connate filaments with two purple longitudinal lines.

Flowers 1 cm long or more; calyx densely hirsute with long hairs; non-reticulate; plants endemic to serpentines on the headwaters of East Austin creek, Sonoma County...4. *S. morrisonii* subsp. *hirtiflorus*.

Flowers less than 1 cm long; calyx glabrous or pubescent, usually reticulate.

Calyx glabrous, rose-purple; plants much-branched; endemic to serpentines in the immediate vacinity of Socrates Mine, Sonoma County...5. *S. brachiatus* subsp. *brachiatus*.

Calyx usually pubescent, yellow or dark purple; plants endemic to Sulphur Creek drainage on the Lake Sonoma County line, and southeast to Mt. St. Helena...6. *S. brachiatus* subsp. *hoffmanii*.

1. *Streptanthus morrisonii* F.W. Hoffman subsp. *morrisonii* F.W. Hoffman

Flowering stems tall (up to 10 dm) and strict; juvenile and adult leaves gray-green on both surfaces, or a little purplish beneath, without maculation; upper stem leaves auriculate—spatulate to auriculate—ovate, sessile, clasping, entire or few-toothed; flowers discretely produced toward the tips of ascending or divergent branches; calyx greenish yellow becoming golden yellow with age, glabrous or with a few scattered hairs, up to 0.8 cm long; petals creamy white to light salmon with brownish or orange-colored veins; siliques erect or divergent, 2.0-7.0 cm long, 0.15 cm wide, straight, or slightly curved, torulose.

TYPE: USA, California, Sonoma Co., serpentine outcrop, head of Big Austin Creek at Layton Mine, 26 Sept. 1946, ***Hoffman 1020*** (UC!)

PARATYPES: USA, California, Sonoma Co., serpentine outcrop, headwaters of Big Austin Creek at Layton Chromite Mine, 26 Sept. 1946, ***Hoffman 1020*** (UC!); serpentine soil, Layton Mine, Austin Creek, 30 May 1947, ***Hoffman 1027*** (UC!); serpentine soil near headwaters of Devil Creek, The Island: tributary of upper East Austin Creek, 19 Aug. 1949, ***Hoffman 2995*** (UC!); serpentine area along Gillian Creek, a branch of East Austin Creek, 30 June 1950, (UC!); serpentine area, trail from Gray Creek to The Island, headwaters of East Austin Creek, 24 May, 1950, ***Hoffman 3360*** (UC!); The Cedars, headwaters of East Austin Creek, exposed barren serpentine bluffs, cliffs, ledges, talus, slopes 700-2000 ft., 6 Aug. 1983, ***Raiche 30581*** (JEPS!)

This taxon occurs on serpentine outcrops in "The Cedars" area of northern Sonoma County, along the drainage of Big Austin Creek and its tributaries.

2. *Streptanthus morrisonii* F.W. Hoffman subsp. *hirtiflorus* F.W. Hoffman.

Strict or much branched and diffuse, up to 8.0 dm tall; upper surface of juvenile leaves heavily mottled with purple—brown, lower surface uniformly purple; upper stem leaves similar to those of the foregoing subspecies; inflorescence secund; flowers abundant, scattered along the flowering branches; calyx somewhate inflated, red-purple, up to 1.0 cm long, abundantly clothed in long hairs (0.2 cm) which gives the plant a grayish appearance; petals dull white with purplish veins, 1.0 cm long; upper filaments broadly connate, orange-colored with two longitudinal, parallel, purple stripes, exserted and curved back over the petals in full anthesis; siliques abundantly produced, up to 10.0 cm long, 0.2 cm wide, erect, divergent, or reflexed on the same plant.

TYPE: USA, California, Sonoma County, on bluffs and cliff talus, serpentine soil, above Dorr's Cabin, headwaters of East Austin Creek, 17 June 1948, *Hoffman 2344* (Holotype, UC!).

Streptanthus morrisonii subsp. *hirtiflorus* grows on serpentine bluffs and talus slopes with western exposure. This rare serpentine endemic occupies an area of not over 100 yd^2 on west-facing serpentine bluffs and slopes at the headwaters of East Austin Creek, a short distance above Dorr's Cabin, Sonoma Co., California. It has not been collected elsewhere.

3. *Streptanthus morrisonii* F.W. Hoffman subsp. *elatus* F.W. Hoffman.

Strict, remotely branched up to 12 dm tall; upper surface of juvenile leaves mottled with purplish brown, lower surface uniformly purple, long-petioled, obovate or fan-shaped, prominently veined, with margins entire basally and coarsely dentate apically; upper stem-leaves oblong—spatulate,

cymbiform, clasping; flowers produced toward the tips of ascending branches; calyx greenish turning golden yellow with age, glabrous or sparsely pubescent, up to 0.7 cm in length; petals white turning yellowish with age, recurved at the tips, lightly veined with purple, up to 0.9 cm long; upper filaments broadly connate, exserted, uniformly greenish yellow, strongly recurved; siliques erect or spreading, up to 7.5 cm in length by 0.15 cm in width, flattened, straight, very torulose.

TYPE: USA, California, Napa-Lake County line, 1/4 mi. west of White's Point, Table Mountain Road, ca. 5 mi. east of Mountain Mill House, 3 May 1947, ***Kruckeberg 1438*** (UC!).

PARATYPES: USA, California, southern Lake Co., serpentine outcrops along ridge from White Point, near Napa-Lake Co. line, 2.7 mi. east of Mt. Mill House, 2500 ft, 5 June 1949, ***Hoffman 2906*** (UC!); 7 July 1949, ***Hoffman 2872*** (UC!); rosettes grown from seed collected at White Point, 4 July 1949, ***Hoffman s.n.*** (UC!); open spot in chaparral; serpentine area along Hoffman Creek, about one mile east of Mirabel Park, 1 Sept. 1954, ***Raven 010745*** (UC!).

Known only from several closely-spared serpentine outcrops near three peaks and White's Point on the Lake-Napa county line.

4. ***Streptanthus morrisonii*** F.W. Hoffman subsp. ***kruckebergii*** Dolan & LaPre' subsp. nov.

Latin description (being prepared).

Loose biennial, plants 30–100 cm tall, remotely branching; rosette leaves green with punctations on top, uniformly purple beneath; stem leaves oblong, spatulate, cymbiform, clasping, often shed before flowering; flowers 0.8–1.0 cm long, calyx yellowish green, turning bright yellow with age; petals creamy white with faint yellow forked midveins which appear purplish with age; upper connate filaments uniformly greenish yellow; siliques straight, 3–5 cm long, glabrous, torulose; seeds usually winged at the tip; cotyledons accumbent.

TYPE: USA, California, Lake Co., Dunnigan Hill in Knoxville Recreation Area (R5W, T11N, Sec11), on serpentine outcrop, 8 June, 1985, *LaPre' S.N.* (holotype, UC; isotypes UC RSA, CAS).

Species associated with *Streptanthus morrisonii* subsp. *knuckebergii* include: *Eriogonum nervulosum, Allium falcifolium, Streptanthus brewerii*, and *S. hesperidis. Pinus sabiniana, Arctostaphylos viscida, Cupressus sargentii, Quercus durata,* and *Ceonothus jepsonii* grew on the adjacent chaparral.

This new subspecies is a morphologically uniform taxon. The plant occurs on scattered serpentine outcrops near the Lake–Napa county line, primarily in the Knoxville Recreation Area (R5W, T11N), Dunnigan Hill region, and associated watersheds.

This taxon is named in honor of Dr. Arthur R. Kruckeberg, leading expert on the serpentine flora of the western United States.

5. *Streptanthus brachiatus* F.W. Hoffman subsp. *typicus*

Strict, often somewhat woody biennial, up to 4.5 dm tall; rosette leaves, glabrous, glaucous, prominently veined, gray-green, mottled with purple—brown above, uniformly purple beneath, petioled (equaling the blade), upper stem

leaves, short—petiolate and sessile, undulate, auriculate, orbicular to orbiculate and oblong—spatulate, prominently veined, up to 2.5 cm in width and 5.5 cm in length; passing into narrowly lanceolate, usually toothed bracts; flowers 0.8 cm long, calyx rose-purple with yellowish base, 0.5—0.6 cm long, surface glabrous and reticulate with base, 0.5—0.6 cm long, surface glabrous and reticulate with fine lines; petals white, 0.8 cm long, recurved, the upper with faint purplish, forked veins, the lower with a deep purple, palmate-branching blotch; the upper set 0.8 cm long, exserted, recurved, filaments orange-colored with two longitudinal purple lines, connate to the reduced anthers, the lower set 0.5 cm long, exserted, recurved, connate for about one-fifth of their length, greenish, with large anthers 0.2 cm long, the lateral set free, 0.4cm long, usually included, with arcuate filaments and large anthers 0.2 cm long; siliques erect, flattened, torulose, purplish, up to 6.5 cm long, 0.15 cm wide; seeds greenish brown, narrowly elliptic, 0.1 cm wide, 0.25 cm long, winged at the tip or not, cotyledons accumbent.

TYPE: USA, California, Sonoma—Lake county line, east of Pine Flat, exposed serpentine ridge near Contact Mine, 3000 ft, 5 June 1949, ***Kruckeberg and Hoffman 2905*** (UC!). Annotation: This locality is near the junction of Socrates Mine Rd. with Pine—Flat—Middletown Rd. on ridge west of canyon of Big Sulphur Creek, Sonoma County. The Napa—Lake county line is on ridge east of canyon of Big Sulfur Creek. H.K. Sharsmith 8 Oct. 1952.

PARATYPES: USA, California, Lake Co., exposed serpentine ridge near Contact Mine, east of Pine Flat, on the Sonoma—Lake county line at 3000 ft, 5 June 1949, ***Kruckeberg and Hoffman*** 2905 (UC!); 29 June 1950, ***Hoffman 3436*** (UC!) summit of ridge about 0.5 mi. south of Mercuryville on road to Big Geysers,

22 June 1950, *Hoffman 3379* (UC!); Sonoma County, serpentine barrens in chaparral near junction of Socrates Mine Rd. with Pine—Flat—Middletown Rd., Mayacamas Mts, 3200 ft, 18 June 1952, *Sharsmith 4129* (UC!).

Streptanthus brachiatus subsp. *typicus* is known only from the immediate vicinity of Socrates Mine on the Sonoma—Lake county line.

6. *Streptanthus brachiatus* F.W. Hoffman subsp. *hoffmanii* Dolan & LaPre' subsp. nov.

Latin description (being prepared).

Loose biennial, habit ranging from short (10 cm) and much branched to tall (30 cm) and remotely branched; rosette leaves green with punctations on the top, uniformly green or anthocyanous purple beneath; stem leaves auriculate oblong to auricualate ovate or lanceolate; flowers 0.7–0.8 cm long, calyx purplish green to greenish yellow, glabrous to hirtilous and variable within a population, the petals white or creamy—white with purple midveins, darker in the lower pair, only the tips exerted beyond the calyx; upper connate filaments with dark-colored longitudinal vascular traces; connective tissue of connate stamens turning yellow with age; siliques up to 5 cm long, straight, glabrous, and torulose; seeds with slight wing along long axis; cotyledons accumbent.

TYPE: USA, California, Lake county near the Sonoma Co. line on Bear Ridge Rd. 1/4 mi. south of three-way junction with Ridge Rd. and Davies Rd., on serpentine outcrop near geothermal expansion joint, 2 May 1985, *LaPre' S.N.* (holotype UC; isotypes UC, RSA, CAS).

Although few plants grow on the serpentine outcrops, species associated with *Streptanthus brachiatus* subsp. *hoffmanii* include *Eriogonum nervulosum, Allium falcifolium*, also rare plants. Growing on the margins of the outcrops in the more weathered serpentine are *Pinus sabiniana, Arctostaphylos viscida, Cupressus sargentii, Quercus durata, Solanum parishii, Fremontodendron californicum* subsp. *napense,* and *Ceonothus jepsonii.*

This taxon occurs on isolated serpentine rock outcrops, occasionally scattered in adjacent chaparral, near the Lake—Sonoma county line (R7W,T10N and R8W,T10N) primarily in geothermal development areas, from the junction of Ridge Road, Davies Road, and Bear Ridge Road off Socrates Mine Road, south to Buck Rock and southeast to Mt. St. Helena. Populations are morphologically uniform within single outcrops but much local differentiation is present between outcrops, even those in close proximity. Calyx color varies most prominently (from purple to yellow) along with stature (from short to tall) along the line from the northwest to southeast. Populations in the southeast nearest the location of *S. morrisonii* subsp. *elatus* tend to converge on morphological characteristics of that taxon. This may reflect an introgressive hybid origin of these populations through evolutionary time. We could not identify any evidence of hybridization occurring.

This taxon is named in honor of Freed Hoffman, an amateur botanist who specialized in serpentine flora. He was the first to collect *Streptanthus* in "The Geysers" region.

Acknowledgements

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Figure 1. Map of type localities of the *Streptanthus morrisonii* complex.

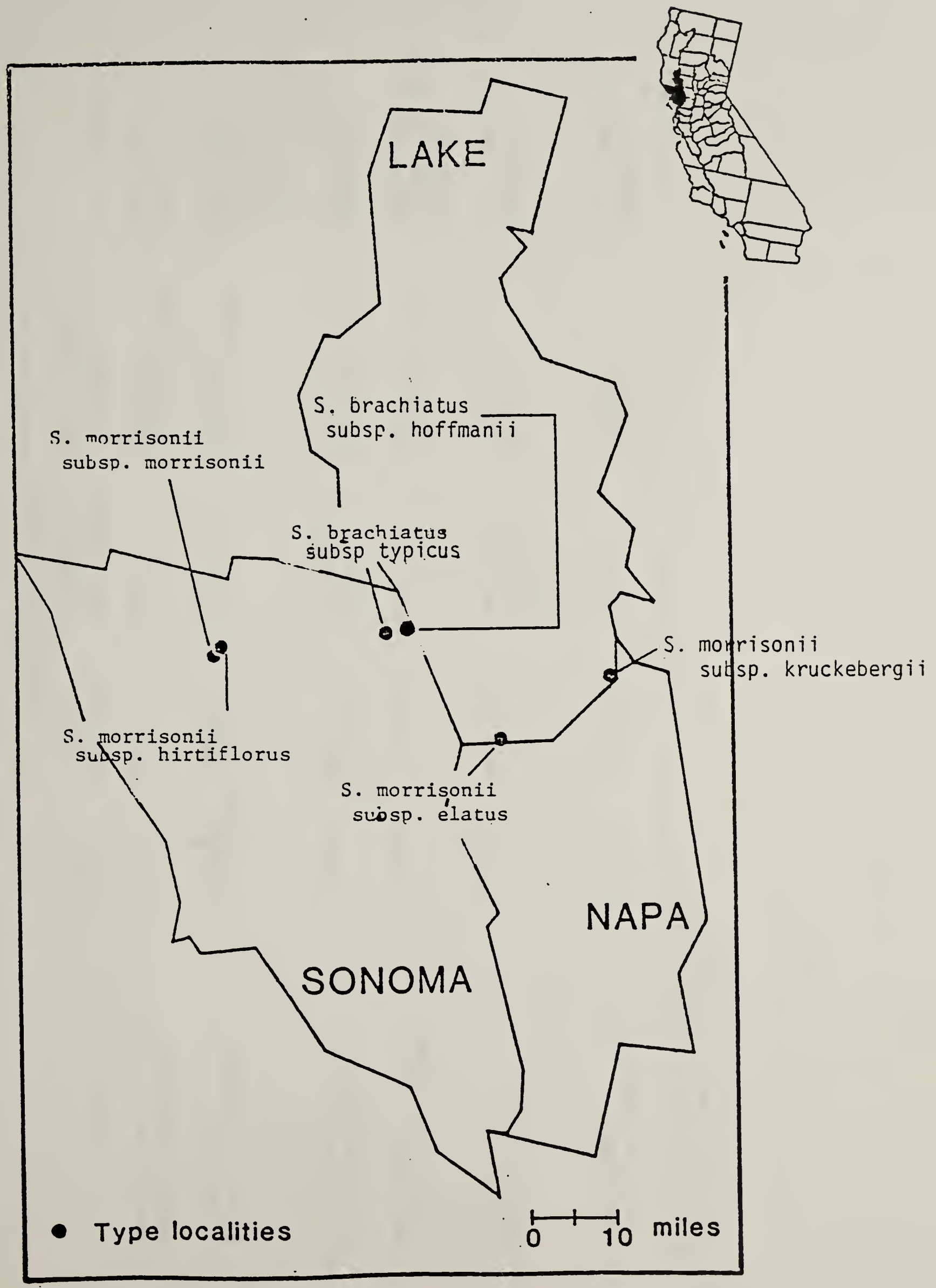


Table 1. Salient distinguishing features of the *Streptanthus morrisonii* F.W. Hoffman complex.

Taxon	Morphological traits				
	Calyx color	Calyx pubescence	Juvenile leaf color	Upper connate filaments	Habit
S. brachiatus subsp. *brachiatus**	purple	absent	mottled	w/purple vascular traces	short, much branched
S. brachiatus subsp. *hoffmanii*‡	yellow or purple	variable	mottled	w/purple vascular traces	short, much branched or intermediate, remotely branched.
S. morrisonii subsp *morrisonii**	yellow	most glabrous	uniformly green	w/orange vascular traces	tall, remotely branched
S. morrisonii subsp. *hirtiflorus**	purple	hirtellous	mottled	w/purple vascular traces	intermediate height, variable branching
S. morrisonii subsp. *elatus**	yellow	variable	heavily mottled w/purple-brown	uniformly yellow	tall, remotely branched
S. morrisonii subsp. *kruckebergii*‡	yellow	variable	mottled	uniformly yellow	tall, remotely branched

*Taxon described by Hoffman (1952)
‡Taxon described in this paper

STUDY SITE SUMMARIES

STREPTANTHUS MORRISONII COMPLEX

Streptanthus morrisonii complex

Study Sites Summary

Introduction

This section summarizes field notes on the sites utilized in this study as representative populations of each taxon in the Streptanthus morrisonii complex. Six sites were chosen in the portion of the Known Geothermal Resource Area (KGRA) currently developed for energy production, in addition to the type locality for each taxon. Factors governing selection of these sites included:

1) ease of access,
2) sufficient numbers of plants for collection.
3) the plants represented the range of variability seen previously in the Streptanthus morrisonii complex.
4) locations studied in the past were utilized so that comparison could be made with previous results.
5) emphasis was given to sites in the KGRA which might be impacted by geothermal development, either currently or in the future.

The locations of the study sites and type localities are illustrated on Maps 1 and 2.

A bound file containing original notes, sketches, maps, charts, and other pertinent data collected during the course of this study is on file at the Bureau of Land Management office in Ukiah. This file is named "Streptathus morrisonii complex: Original field notes and background data".

This section includes the supporting data for the status and management recommendations for each taxon. Summaries are given in each of several categories, which are explained below:

Observations

Information from field notes about access, population vigor, associated plants, human impacts, and vulnerability to disturbance is put under this heading.

Population size

Two methods of tallies were utilized: counts and estimates. Counts are the recorded numbers of adult plants observed at a site, based on as thorough ground coverage as possible, sometimes with transects spaced as close as two meters apart. Estimates are extrapolations of counts to a larger area, such as an entire barren, and are given to the nearest order of magnitude. Because of the difficulty of seeing the plants and the rugged terrain, more confidence is placed on the estimates than on the counts, except on very small sites where complete coverage was possible.

Area

Estimates of area were made from topographic maps and aerial photographs, using graph paper calibrated to the given scale. Aerial photos were available for the KGRA from 1984, for Socrates Mine from 1971 and 1980, for The Cedars in 1980, and for Knoxville from 1985.

Study plots

Research in the KGRA has included a study of boron emmissions effects on Streptanthus populations by Susan Mazer of UC Davis, a soils study of several barrens by UC Davis, and the electrophoresis experiments and seedling plots conducted for this study. These study sites are indicated where appropriate.

Associated species

An attempt was made to document the dominant vegetation at each study site. Specimens of the most common perennial shrubs were collected from each site, and these were deposited in the herbarium at the University of California, Riverside campus. There was no concerted attempt to document all of the flora at each study site, but a substantial percentage of the plants were collected over the three year period. All or nearly all of the species found on the barrens with the Streptanthus morrisonii complex have been documented.

Ownership

Many of the Streptanthus sites were discovered to have complex ownership patterns, including mines that existed before California became a state, divided property rights, separate geothermal leases, and a mixture of federal, state, and private parcels.

The lessees and operators in the developed part of the KGRA are not listed or mapped. These properties are indicated as federal or state leases. Ownership records listed for private parcels are current as of July 1986.

LEGEND

TYPE LOCALITIES

(11) Dorr's Cabin (S. morrisonii ssp. hirtiflorus)

(12) Layton Mine (S. morrisonii ssp. morrisonii)

ADDITIONAL SITES

(13) Red Slide (S. morrisonii ssp. morrisonii)

Scale: 1 : 164,000

N

Streptanthus Study Sites – Map 2

Tierra Madre Consultants

Source: U.S.G.S. Point Arena, CA. 30x60 minute series

LEGEND

TYPE LOCALITIES

① Socrates Mine (S. brachiatus)
② Three Peaks (S. morrisonii ssp. elatus)

ADDITIONAL SITES

③ Davies Road
④ Expansion Joint
⑤ Q-pad 1984
⑥ Q-pad 1985
⑦ Ridge in between
⑧ B-pad
⑨ M-pad
(S. brachiatus hoffmanii)

⑩ Knoxville (S. morrisonii kruckebergii)

—— main area of current geothermal development

– – – – K.G.R.A. boundary (approx.)

Public land

Scale: 1 : 164,000

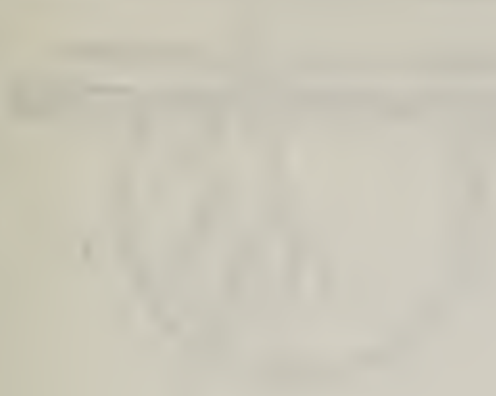
N

Streptanthus Study Sites – Map 1

STREPTANTHUS MORRISONII COMPLEX

Source: U.S.D.I., B.L.M. Surface–Mineral Management Status, Healdsburg Quad., CA.

Tierra Madre Consultants



Name: Dorr Cabin - (Austin Creek area)

Location: Cazadero quad (R 11 W, T 9 N, Sec. 17)
Sonoma County

Species: Type locality for S. morrisonii ssp. hirtiflorus.

Dates visited: 1986: May 7-8, June 3

Observations:

A helicopter flyover on June 7, 1985 showed this area to be about two small ridges of serpentine barrens located in the center of a vast outcrop of greywacke.

The population was described by Hoffman as very restricted, occupying an area of less than 100 square yards at the one known location. This was verified on the field visits, where only ten mature plants were located, with about 100 plants making up the total population. A search of the rock outcrop failed to detect any other locations besides the small slide immediately behind Dorr Place. The area of occurrence is about one acre at the most.

The flowering Streptanthus plants at Dorr Place definitely appeared different from those at Red Slide or the Cedars, as described by Hoffman. The major differences were in the color and hairiness of the calyx, as well as in the flowering time. The plants are definitely biennial, as several rosettes were seen at the same time as the adult flowering plants. Each adult plant had many (hundreds) seeds in June. Oddly enough, Streptanthus glandulosus, which occurs as a purple annual with the yellow S. morrisonii at Red Slide, was found to be yellow at Dorr Place, while the S. morrisonii are purple. There could be something peculiar about the mineral composition at this site which influences the flower color.

Population size:

The total count after a thorough search in 1986 was 10 adult plants and about 100 rosettes.

Area:

Hoffman reported the total area behind Dorr Place containing the Streptanthus plants as 100 square yards. This was verified by the field visits, and the total area was estimated at less than one acre.

Samples taken:

Flowers were gathered for electrophoresis experiments in May and June, 1986. Herbarium collections were made for adult plants and seedlings, and seeds were collected in June, 1986.

Associated species:

These plants were collected at this site:

Linaria canadensis
Streptanthus glandulosus
Streptanthus morrisonii hirtiflorus
Antirrhinum cornutum
Arenaria douglasii
Mimulus nudus

Ownership:

Private. No legal access to the site or even on the roads leading up to the site. The visit was made by walking from Bullfrog Pond at Austin Creek State Recreation Area to Mannings Flats, where an overnight camp was made. The site was then reached by walking out of the Park onto private roads up to Dorr Place. Two locked gates were crossed. Round trip distance from Bullfrog Pond = 14 miles. In May, the private dirt roads were inaccessible by car due to a landslide over the road and several washouts. These were repaired by early June.

Ownership of the serpentine barrens in central Sonoma County near the Cedars is a complex mixture of federal and private holdings, with a small acreage of State lands. Two type localities are included in this area, that of S. m. var. morrisonii and of S. m. var. hirtiflorus. The owners of properties in this area are illustrated on Map 3 and listed below (numbers keyed to Map 3).

1) Jones, J. B. and Cleo R.
   2140 Los Angeles
   Berkeley, CA. 94707

2) United States of America

3) DeCarly, Richard James, and Daniel, Norman, et al
   P.O. Box 274
   Guerneville, CA. 95446

4) Red Slide Mountain Properties
   c/o Everett Shapiro
   1208 Fourth St.
   Santa Rosa, CA. 95404

5) Twitchel, Donald L. & Bette A.
   P. O. Box 480
   Cazadero, CA 95421

6) Savio, Edward
   Edward F. & Coragene, I. & Edward II
   10 Digby St.
   San Francisco, CA 94131

7) Forney, Clinton D.
   693 Petaluma Blvd. North
   Petaluma, CA. 94952

8) Headwaters Ranch, Inc.
   c/o N. Maroni
   434 College Ave.
   Santa Rosa, CA. 95401

Map 3 Ownership - The Cedars
Streptanthus morrisonii morrisonii
Streptanthus morrisonii hirtiflorus

0 .5 1
Scale (miles)

Serpentine barrens

00 Owner # (#2-USA)

Tierra Madre Consultants

Name: Red Slide & The Cedars - (Austin Creek area)

Location: Cazadero quad (R 11 W, T 9 N, Sec. 20)
Sonoma County

Species: Streptanthus morrisonii var. morrisonii

Dates visited: 1986: June 2-3, August 28

Observations:

Red Slide is a natural landmark that can be seen from many miles distant. Most of the Streptanthus plants are located at the bottom of the slide among larger rocks and boulders. Streptanthus glandulosus is present as well as S. Morrisonii. Typical serpentine indicator plants are found in the area.

The Cedars is a vast area of serpentine chaparral and barrens owned mainly by the Bureau of Land Management. Access is difficult, if not impossible, since the surrounding landowners will not grant access. A helicopter trip was made to the barrens at The Cedars in 1985.

This area includes Layton Mine, the type locality for S. morrisonii var. morrisonii. Our study site for this taxon was Red Slide because the access is easier.

Population size:

Coverage was not complete within the entire range of this taxon. Based on the numbers observed in the portion of The Cedars visited, and at Red Slide, the total for all available habitat is estimated at between 1,000 and 10,000.

Area:

The amount of suitable barrens habitat measured from aerial photographs is 912 acres. The ten isolated barrens are located on portions of nine sections.

Samples taken:

Flowers were collected for electrophoresis in June 1985 from The Cedars, and in June 1986 for Red Slide, as were herbarium specimens. Seeds were collected in June and late August, 1986.

Associated species:

Cupressus mcnabiana, Quercus durata, Ceanothus spp., Arctostaphylos spp. were typical serpentine chaparral nearby. Phacelia corymbosa and Eriogonum ursinum were on the barrens at the Cedars with Streptanthus morrisonii. Eshscholzia californica was present on the barrens at Red Slide, as was Antirrhinum cornutum.

Ownership:

A mixture of public lands and private property. About one half of the serpentine barrens are on public lands. Red Slide is leased to the Red Slide Gun Club for hunting of feral pigs. Land ownership of serpentine barrens habitat at The Cedars and near Red Slide is given on Map 3 and the following pages.

Name: Socrates Mine

Location: The Geysers quad (R 8 W, T 11 N, Sec. 32 & 33)
Two isolated sites in sections 30 & 31.
Sonoma County

Species: Streptanthus brachiatus type locality

Dates visited: 1985: March 20, April 29, June 5, 23, 27, Aug. 8
1986: Mar. 30, 31, May 9, 31, July 29, 30, Sept 1
1987: June 27, June 29, July 3

Observations:

Socrates Mine has four population loci: 1) the main barrens, which is mostly disturbed by mining, 2) a small natural barren surface to the north, which has been cut by a ridgeline access road, 3) the transmission line tower, located about one half mile north of Socrates Mine, and 4) the open chaparral about one quarter mile east of the transmission tower. These latter two areas were monitored by Nancy Crane of PG&E. Two other locations are known: a very small barren surface is located about 1.2 mile north of Socrates Mine in the SE 1/4 of Section 30 along the ridge road (Cadd Fire Trail), and the Ivana Roland site, a transmission line tower 1/2 mile south of Cadd Fire Trail, about 2 miles west of Socrates Mine in section 31. The barren slide along the ridge road was visited several times, and a few Streptanthus brachiatus plants were found. The Ivana Roland site was visited in 1987, and the small population was censused.

Two historic localities (labelled on herbarium specimens) are known for Streptanthus brachiatus as well. One is a ridge of open serpentine chaparral just west of Mercuryville, while the other is the Contact Mine, a location believed to be erroneous, according to Hoffman. These localities are shown on Maps 4 and 5, along with the probable maximum limits of the geographic distribution.

Socrates Mine is a former barrens that has received extensive disturbance from past mining operations and from transmission line construction. Much of the mined surface has been reclaimed by deposition of fill material from Unit 18, which covered the excavation, leaving a grassy hillside with terrace drains. The remaining serpentine consists of cut slopes, excavated ridgelines, and disturbed rock outcrops. Less than one acre of naturally barren surface remains. Streptanthus brachiatus occurs on the roadcuts, tailings, cut slopes, open chaparral, and on the two native surfaces. Most occurrences are on rocky outcrops or surfaces that have received the least disturbance.

Population size:

In June, 1985 35 adults were counted inside the fence, with 74 plants outside. An estimate of total plant numbers in 1985 was 100 - 1000.

Name: Socrates Mine (cont).

A careful count of all areas of occurrence of S. brachiatus was made in 1986. On March 31, counts yielded: Socrates Mine = 392, most tiny seedlings and small rosettes, with 20-30 plants inside the fence, 25 seedlings seen inside the fence, and only one plant seen outside. Other sites yielded: natural surface = 52 seedlings, T/L tower = 1, open chaparral = 2, barren slide = 2 rosettes. On May 31, most plants were in flower or had buds. Counts were: Natural surface = 13, barren slide = 24, no more than 100 total. On July 30, the natural surface had 0 plants, and the T/L tower site had 14. Overall, the same conclusion was reached as in 1985 for the number of S. brachiatus plants in the Socrates Mine area: the total number does not exceed 1,000.

The S. brachiatus plants were recounted in 1987. 228 adult plants were recorded near the wood pole and the area north to the fencing. 127 plants were tallied within the fence, and 20 adults were detected outside the fence. At the natural surface were 10 plants, 5 on each side of the road. The Nancy Crane T/L site contained 24 adults and 25 rosettes. The barren slide had 31 adults. The Ivana Roland site near the Cadd Fire Trail had 59 adults.

In each succeeding year, a few more plants were noted re-establishing in the compacted road and tailings area adjacent to the fence.

Area:

Populations occur in portions of four sections. The total amount of barrens surface occupied is less than 20 acres. Areas of each occurrence are:

Socrates Mine = 10 acres (includes T/L tower site)
Open chaparral = 100 acres, no barrens over one acre
Cadd Fire Trail = 3 acres
T/L Ivana Roland = 2 acres
Mercuryville = 5 acres

Estimated population size: Less than 1,000 at all sites.

Socrates Mine = 500
Open chaparral = 10 adults seen 1985 & 1986
Cadd Fire Trail = 1987 = 31 adults
T/L Ivana Roland = 1987 = 61
Mercuryville = 0

Study plots:

Two seedling survival plots (each 1 m^2) were established and the numbers were counted on visits from March 1985 until August 1986. Considerable year-to-year variation was evident from the seedling survival plots for the two years.

Samples taken:

Herbarium specimens of this taxon at all stages have been collected. Seeds were collected in 1985, 1986, and 1987. Electrophoresis experiments were run on plants from this site in 1985 and 1986.

Name: Socrates Mine (cont).

Associated species:

These species from Socrates Mine and along the ridge towards Mercuryville have been collected, pressed, and identified at the University of California, Riverside herbarium:

Epilobium minutum
Eriogonum vimineum
Arctostaphylos viscida
Eriophyllum lanatum
Fritillaria recurva var. coccinea
Centaurea solstitialis
Monardella odoratissima ssp. pinetorum
Castilleja roseana
Lotus humistratus
Calyptridium quadripetalum
Eschscholzia californica var. crocea
Hemizonia luzulaefolia
Chenopodium botrys
Allium falcifolium
Ceanothus jepsonii
Brodiaea laxa
Onychium densum
Sitanion jubatum
Rhamnus californica
Senecio greenei
Streptanthus glandulosus
Streptanthus brachiatus

Ownership:

Ownership maps were obtained from the Ukiah District Office of the BLM and the Sonoma County Assessor's Office. These showed a very complex ownership pattern, with a split estate for most holdings, irregular parcel shapes, and uncertain boundaries of the barrens, since the topography has changed so much from the mapped topographic lines.

The ownership rights for much of the Socrates Mine area have been divided and sold separately, including the surface rights, mineral rights, and oil and gas rights. Much of the surface and all of the mineral rights are leased for geothermal development. Socrates Mine and the surrounding areas are within the lease for Unit 20. Unocal provided a map of the areas they control by lease or in fee. Their ownership interests cover nearly the entire geographic range of this taxon, including most of the known sites. Other owners of mineral rights on lands within the range of S. brachiatus include Geysers Geothermal Company and Grace Geothermal Corporation. PG&E has a major transmission line with two towers located on or near populations. The small natural barren surface northwest of Socrates Mine and possibly other population sites may be within the transmission line easement.

No active placer or lode mining claims are present at Socrates Mine. Maps 4 & 5 illustrate the ownership interests of parcels in the Socrates Mine area. Only a small part of the Streptanthus brachiatus populations are within federal surface or mineral rights ownership.

Map 4

Streptanthus brachiatus

Geographic range

☆ Existing populations

☆ Historic records

Surface Ownership:

BLM

Private

Access Road

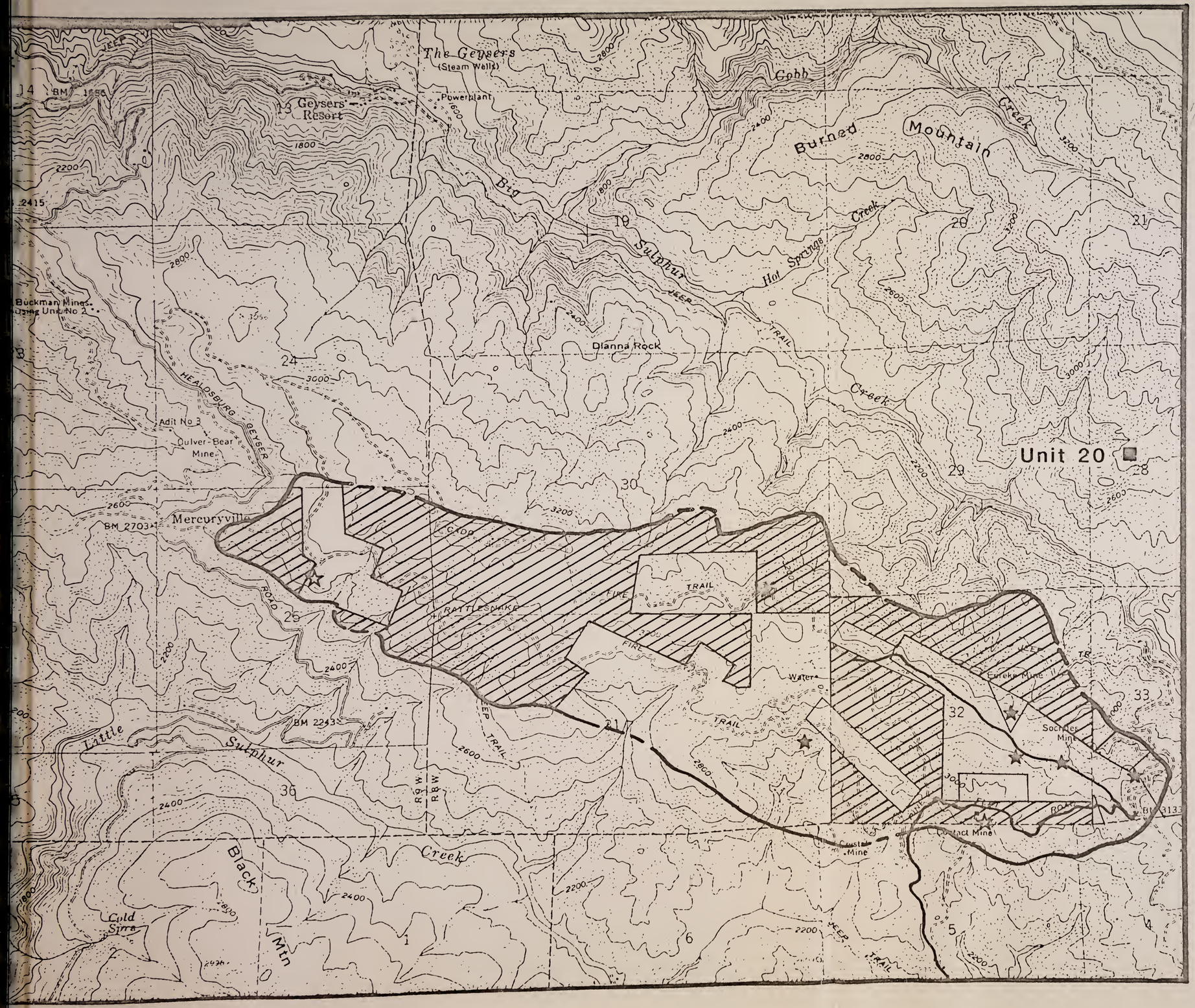
0 .5 1

Scale of miles

Tierra Madre Consultants

N

Map Source: The Geysers



Map 5

Streptanthus brachiatus

Geographic range

☆ Existing populations

☆ Historic records

Mineral Rights Ownership:

BLM

Private

Access Road

0 .5 1

Scale of miles

Tierra Madre Consultants

N

Map Source: The Geysers

Name: Three Peaks

Location: Detert Reservior Quad (T 10 N, R 6 W, Sec. 19 & 30)
T 10 N, R 7 W, Sec. 24 & 25)
Lake County (near Napa County line)

Species: Streptanthus morrisonii ssp. elatus type locality

Dates visited: 1985: Feb 5, Mar 18, Apr 24, May 3, 6, June 6, 28, Aug 11
1986: March 30, May 6,31, July 14, August 30
1987: July 5, 28

Observations:

This barrens is in Lake County near the Napa County line. It is reached via Livermore Road, which is paved off Highway 29 (at Mountain Mill House Girl Scout Camp) but turns to dirt at the entrance to Livermore Ranch and Montesol (bear left). Herbarium collections generally term this site "Three Peaks", "White's Point", "Table Mountain Road", or "Livermore Road".

The Streptanthus morrisonii var. elatus plants at this site appear to be thriving, but are never numerous and exhibit a patchy distribution. Flowering adults are tall, especially in wind-protected microsites. Substantial browsing by deer and rabbits and insect feeding on the flowers was observed throughout the spring and summers of 1985, 1986, and 1987. The plants send up smaller flowering stalks in August or September if browsed earlier.

An undescribed species of annual Streptanthus occurs at this site. This plant sould be a significant range extension for Streptanthus batrachopus, a species known from Mount Tamalpais.

The barrens surface at Three Peaks has received heavy disturbance in the form of roads and trenching in the past.

Population size:

Total counts never exceeded 1,000 plants in 1985, 1986, or 1987, and were generally less than 500. The estimated total of plants in this taxon is 1,000 - 2000 adults.

Area:

The serpentine barrens occur on portions of four sections. The barren surface totals only 92 acres, all located within larger parcels of public land. The Bucksnort Creek site occupies about 20 acres, though the Streptanthus population is marginal.

Study plots:

Two seedling survival plots (each 1 m^2) were established at the small barrens on the south, and seedlings were first counted on April 24 and May 6, 1985. Repeated counts of these plots continued in 1986. Survival as rosettes through the summer varied from 30% to 60% in the favorable location of the plots. Other sites, where seedlings were noted but not tallied, suffered greater mortality from dessication.

Name: Three Peaks (cont).

Samples taken:

Flower samples for electrophoresis experiments were collected on several dates in 1985 and 1986, providing several replicates of the biochemical data. Herbarium specimens of S. m. var. elatus at all stages have been collected from this site. Seeds were collected August 30, 1986 and in 1987.

Collections were made of the beetles that eat the flowers heavily during the late spring. Dr. Charles Howell, an entomologist from Redlands, identified these beetles as being an unidentified species of the genus Eutricholistra (Dasytidae).

Associated plants:

Two other species of Streptanthus are present at Three Peaks: S. breweri and a new species of annual Streptanthus, termed var. tuckeri by Neilson. This plant may be S. batrachopus.

Associates include Cupressus sargentii, Ceanothus jepsonii var. albiflorus, Quercus durata. Scattered Pinus sabiniana are found within the barrens. A lot of dead wood from manzanita and pines lies on the ground. Few annuals are present, except for other Streptanthus and a small Eriogonum. These additional species have been collected, pressed, and identified by the University of California, Riverside herbarium:

Three Peaks barrens (on serpentine rock)	Livermore Road (chaparral)
Erythronium helenae	Pedicularis densiflora
Arctostaphylos viscida	Pickeringia montana
Arenaria douglasii	Quercus chrysolepis
Allium falcifolium	Quercus durata
Claytonia spathulata	Arctostaphylos manzanita
Ceanothus jepsonii var. albiflorus	Lupinus sericatus
Ceanothus cf. lemmonii	Gallium sp.
Epilobium minutum	Ceanothus foliosus
Ceanothus divergens ssp. confusus	Ceanothus parryi
Streptanthus morrisonii var. elatus	Whipplea modesta
Hesperolinon spergulinum	Penstemon heterophyllus
Senecio greenei	Gallium andrewsii

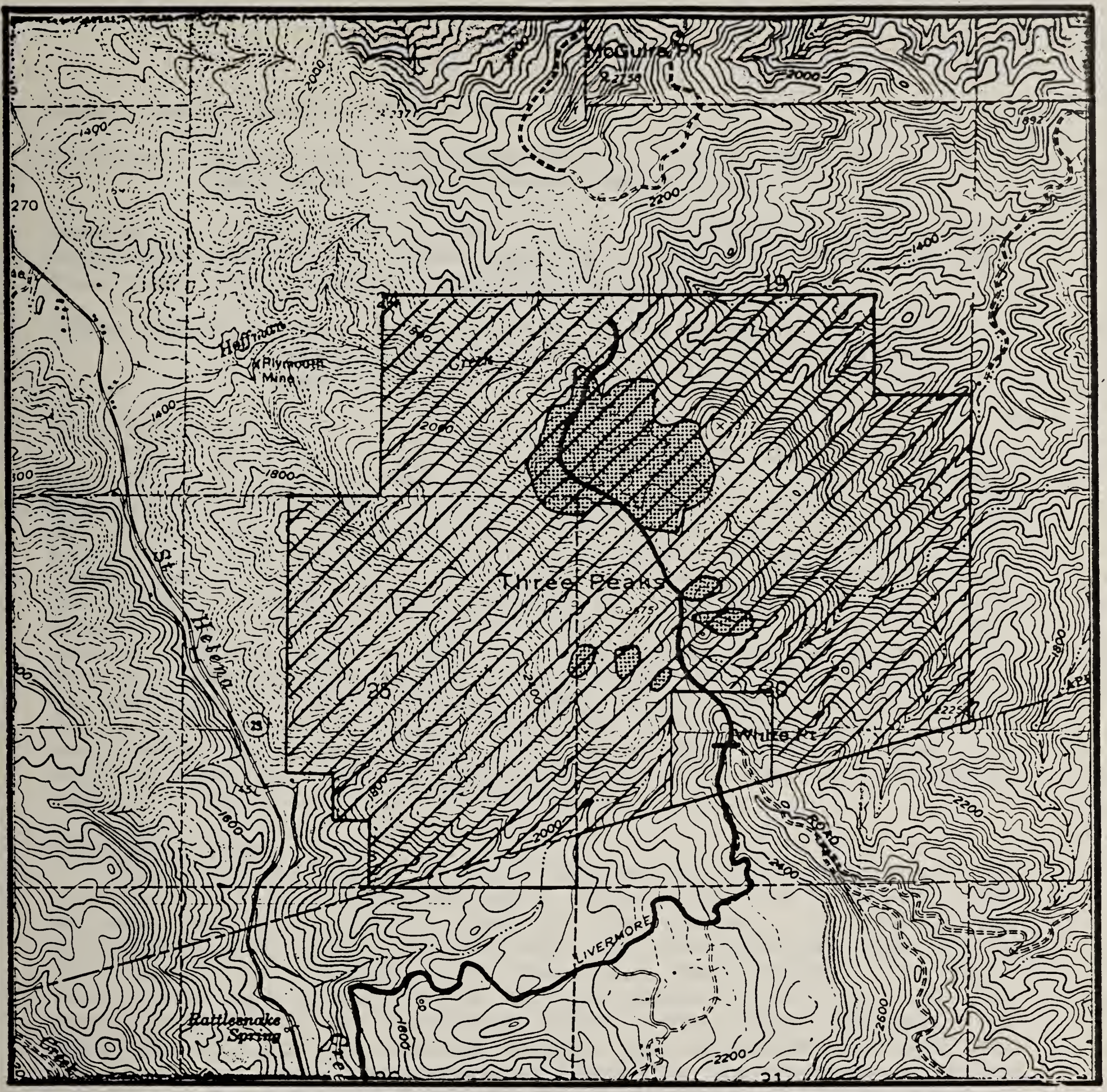
Ownership:

Ownership is BLM. A cable blocks a dirt road leading into the barrens, which is on a private parcel. This private parcel is owned by Montesol Co., 414 Mason St. #802, San Francisco, CA 94102. There appears to be very little visitation to this site by anybody.

A diagram of ownership in the Three Peaks area is presented on Map 6. The surface minerals management map for Healdsburg, along with a topographic map provided by BLM which shows federal holdings, do not match the parcel boundaries or owners provided by the Lake County Assessor's Office. The area is a mix of lands

Name: Three Peaks (cont).

owned by the State of California, the United States of America, and the Livermore family, which controls the large Livermore Ranch, a series of walnut orchards, a woodcutting operation, and a hunting club called Montesol Hunting Club. Some mineral rights are reserved by the federal government on the State lands. Nearly all of the Streptanthus plants are located on federal lands.



Map 6 – Ownership

Streptanthus morrisonii elatus type locality
Three Peaks

N

0 .5 1

Scale of miles

Legend

- Access Road
- Locked Gate
- Serpentine Barrens
- BLM
- Private

Map Source: Detert Reservoir

Tierra Madre Consultants

Name: Davies Road (KGRA)

Location: Whispering Pines quad (R 7 W, T 10 N, Sec. 2)
Lake County (near Sonoma County line)

Species: Identified in past as S. morrisonii complex. This population was called variant majorii by Neilson (1977). We name this taxon Streptanthus brachiatus hoffmanii.

Dates visited: 1985: Feb 5, Mar 20, May 2, June 4, 26, Aug 10
1986: March 29, May 5, June 1, 25, July 15
1987: July 5

Observations:

This site is a portion of the main barrens that is surrounded by geothermal development (Map 7). It is reached from Davies Road, about one-half mile east of its junction with Bear Ridge Road. The collection locality is at the edge of the barrens on a ridgetop about a third of a mile downhill from Davies Road (no trail). A red flag is tied onto a pine to mark the main collecting site; another red flag was tied to a pine tree at the bottom of the drainage below the ridge to mark another concentration of plants. The plants at the Davies Road site are consistantly purple, while those only one half mile to the east are yellow in flower color. The Davies Road population also appears to be more branched near the base, and is reminiscent of S. brachiatus at Socrates Mine. The flowers are eaten by beetles, but the population is not as heavily browsed by deer as those plants at Socrates Mine.

Population size:

The initial counts of adult plants at the Davies Road site in March 1985 yielded an estimate of perhaps 1000 plants in the barrens near the flagged tree on the ridge. As the spring progressed, the plants became less and less obvious, due mainly to browsing and trampling by deer, and dessication. In 1986, less than 100 plants were at the same location, and few concentrations of any size were noted. The total population at this site and the surrounding barrens was estimated at less than 500 plants in 1986. The estimated total for the barrens extending downslope from Davies Road to the tributary of Bear Creek is 100-1,000 plants.

Area:

The barrens between Davies Road and Bear Ridge Road, which include the Davies Road site and the Expansion Joint site, total 28 acres.

Study plots:

One seedling survival plot was established in March 1986. All but one of these second year rosettes grew to maturity. Two of the seventeen adult plants had poor seed set.

Name: Davies Road (KGRA) (cont).

Samples taken:

Flower collections for the electrophoresis experiments were collected several times during 1985, 1986, and 1987.

Herbarium specimens from the Streptanthus plants at all stages have been collected.

Seeds were collected in July, 1986 and July, 1987.

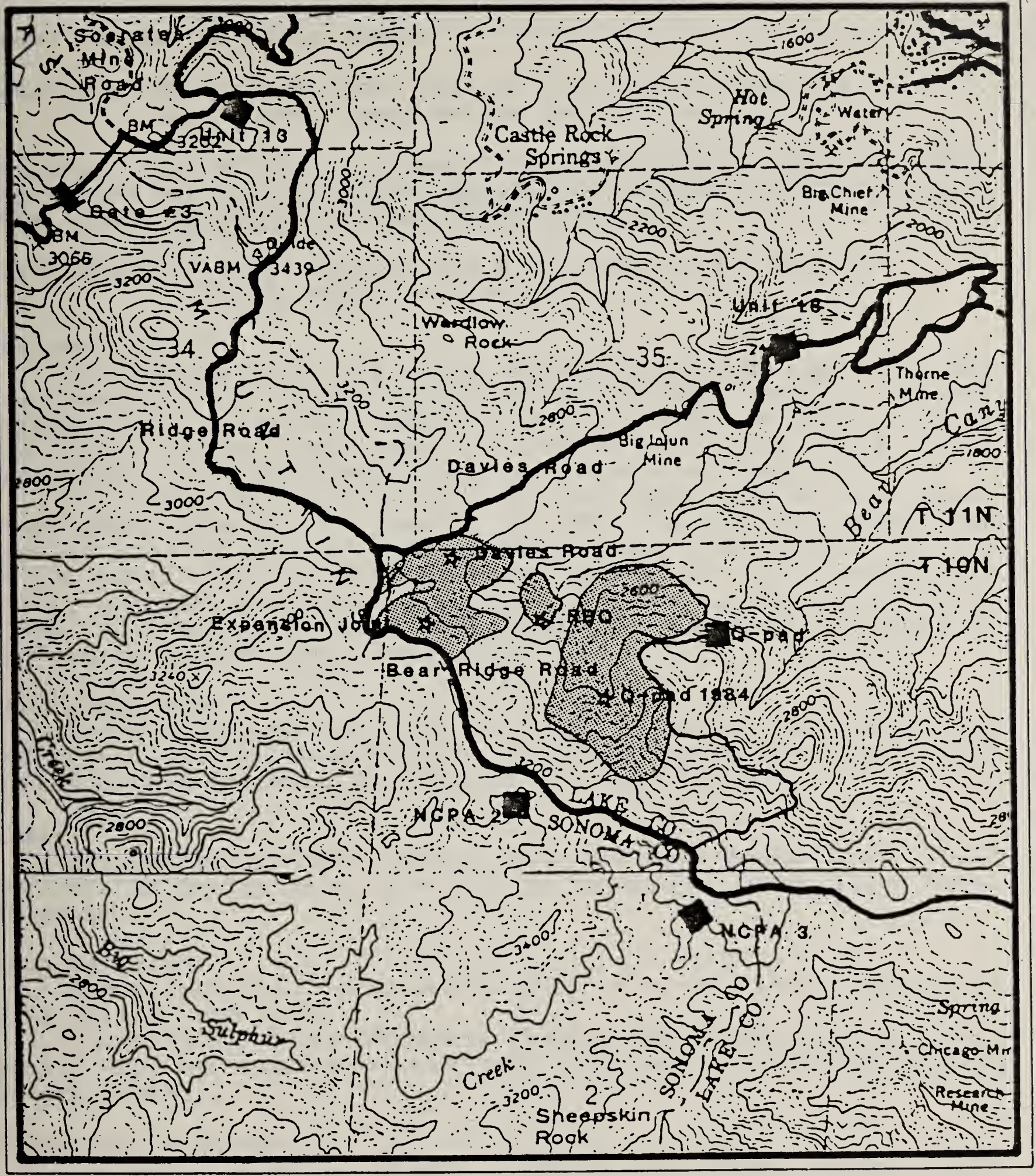
Associated Species:

Associates included Pinus sabiniana with several Streptanthus plants growing in the pine needle leaf litter. Many dead Arctostaphylos were present at this site. Other associates represented by herbarium specimens are:

Ceanothus cuneatus
Arctostaphylos viscida
Quercus durata
Solanum parishii
Fremontodendron californicum ssp. napense
Ceanothus parryi
Tunica prolifera

Ownership

Federal or state geothermal lease.



Streptanthus Study Sites – Map 7

Streptanthus brachiatus hoffmanii

Legend

- Access Road
- Locked Gate
- Geothermal Facility
- Serpentine Barrens
- Streptanthus Study Site

N

0 .5 1

Scale of miles

Tierra Madre Consultants

Base: Mt. St. Helena & Whispering Pines

Name: Expansion Joint (KGRA)

Location: Whispering Pines quad (R 7 W, T 10 N, Sec. 2)
Lake County (near Sonoma County line)

Species: Identified in past as S. morrisonii complex. This population was called variant majorii by Neilson (1977). We name this taxon Streptanthus brachiatus hoffmanii.

Dates visited: 1985: Mar 19, May 2, 5, June 4, 26, Aug 11.
1986: March 30, July 15

Observations:

Accessible from the first expansion joint south of the intersection of Davies Road and Bear Ridge Road. Several Streptanthus plants were observed growing near the road in March and April, 1985. The site is behind a barbed wire fence indicating a BLM environmentally sensitive area (Map 7).

The plants appear to flower and set seed earlier than those from study sites to the east. In 1985, nearly all plants had gone to seed by June 26, and the same stage was reached on July 15 in 1986. The total number of plants at this location is small, and like the Davies Road site, varied in location between years. All plants seen in this population appeared identical to the plants at the Davies Road site.

Population size:

Several censuses in 1986 and 1987 indicated that less than 100 plants grow on these barrens from Bear Ridge Road down to the bottom of the drainage, a tributary of Bear Creek.

Area:

The barrens between Davies Road and Bear Ridge Road, which include the Davies Road site and the Expansion Joint site, total 28 acres.

Samples taken:

Electrophoresis experiments were run on plants from this site in 1985 and 1986.

Seeds from twenty separate plants were collected in July, 1986. Pressed specimens have been obtained of these plants on several dates.

Associated species:

Virtually no other plants occur on the barren areas except Eriogonus nervulosum, Dentaria californica, Eriogonum vimineum, and Eriogonum ursinum.

Ownership:

Federal or state geothermal lease.

Name: Road below Q (RBQ), also called Ridge-in-between. (KGRA)

Location: Whispering Pines quad (R 8W, T 10N, Sec. 2)
Lake County

Species: Identified in past as S. morisonii complex. We name this taxon S. brachiatus hoffmanii.

Dates visited: 1985:
1986: March 29, May 5, June 1, July 15
1987: July 28

Observations

The best access is from an abandoned dirt road leading off Davies Road, but the site can also be reached from Q pad, taking another abandoned dirt road that begins at the base of the fill material (Map 7).

This site was selected because it lies between the purple-flowered forms at Davies Road and the Expansion Joint site and the yellow-flowered forms at Q pad and all points east. The flower color of plants at this site is often yellow with a purple tinge, and the stature, branching pattern, and phenology suggest an intermediate position between the populations to the east and to the west. At the time of seed set in 1985, it was noted that very few individuals in this population carried viable seed; the same was true for 1986. There were, however, a few outstanding plants with many seed pods, a rare exception among the dozens of plants with no seeds at all. No plants in this population look identical to those from Davies Road, i.e. low stature with many branches and purple flowers with glabrous calyxes, even though the Davies Road site is only a few hundred meters to the northwest. The plants at the road below Q pad (RBQ) are more similar to those found at B site and M site, based on field observations.

Population size:

The estimate of population size for this area is 100 -1,000.

Area:

The area of the barrens extending from the bottom of the drainage below Q Pad up onto the slope before merging with the larger Q Pad 84 barrens is 5.5 acres (Map 6).

Study plots:

Four seedling survival plots were established at this site. Survival of rosettes over the summer was variable.

Samples taken:

Several herbarium specimens have been made from this intermediate appearing population. Electrophoresis experiments were run on flowers from this site in 1986. Few seeds were available in 1986.

Name: **Road below Q (RBQ), also called Ridge-in-between. (KGRA)** (cont).

Associated species:

The barren ridges contain the typical serpentine indicator species, such as Quercus durata, Pinus sabiniana, Arctostaphylos spp., and the rare Eriogonum nervulosum. Specimens collected and made into herbarium sheets include:

Pedicularis densiflora
Dentaria californica
Trichostema laxum (Big Injun Mine)
Eriogonum umbellatum

Ownership

BLM or State of California geothermal lease.

Name: Q-Pad 1985 (KGRA)

Location: Whispering Pines quad (R 8W, T 10N, Sec. 1 and 2. Lake County

Species: Identified in past as S. morrisonii complex. We name this taxon S. brachiatus hoffmanii.

Dates visited: 1985: May 4, June 4, August 10
1986: March 30, May 5, July 15, August 30
1987: July, Aug

Observations:

This site is accessed from near the top of the Q-Pad road where it takes a sharp bend to the left, heading downhill (Map 8). A trash can and small turnout are at the parking area. Walk east through the pygmy forest of Cupressus to reach the barrens. The rocks are brown at this site. The plants here are short, and few in numbers, similar to the population at B site.

Population size:

The estimated population at this site is a maximum of 200 adult plants.

Area:

The surface area of this isolated barrens is 19 acres.

Study plots:

Susan Mazer of UC Davis had ten 2m x 2m plots located at this site in 1984.

Soil samples from the UC Davis study have been taken from here.

Three seedling survival plots were established in 1986 at this location. Survival of rosettes over the summer averaged 14%.

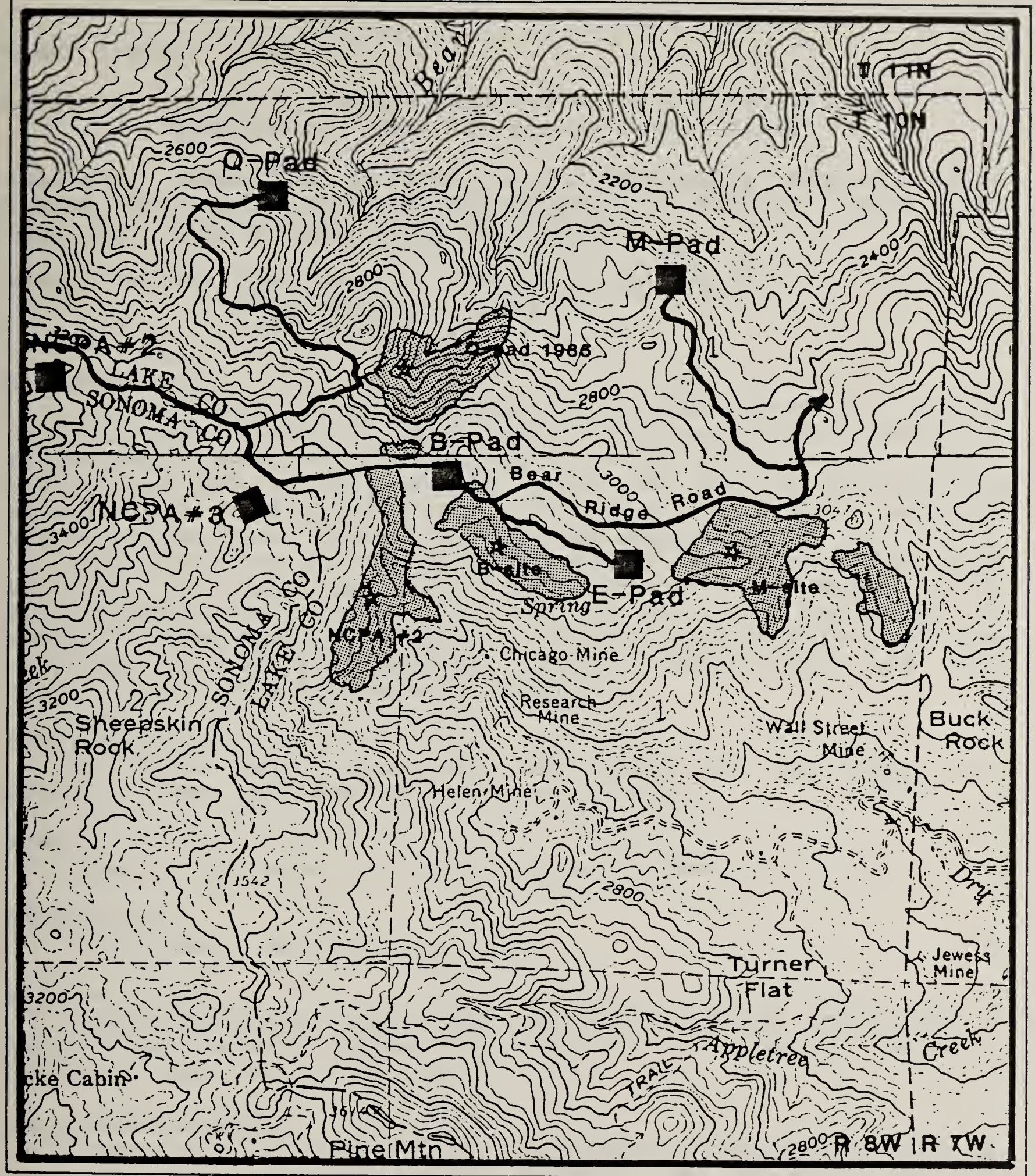
Samples taken:

Pressed specimens of both seedlings and of flowering plants have been collected.

Seeds were collected in August, 1986 and July, 1987.

Associated species:

Allium falcifolium, Eriogonum nervulosum on the barrens, along with many large dead Arctostaphylos. The barrens are surrounded by a pygmy forest of Cupressus and Arctostaphylos. Scattered Pinus sabiniana are present. Trichostema laxum and Eriogonum umbellatum were also collected.



Streptanthus Study Sites -Map 8

Streptanthus brachiatus hoffmanii

Legend

- Streptanthus Study Site
- Geothermal Facility
- Access Road
- Serpentine Barrens

N

0 .5 1

Scale of miles

Tierra Madre Consultants

Name: B-Site. (KGRA)

Location: Mount St. Helena quad (R7 W, T 10 N, Sec. 1)
Lake County (near the Sonoma County line)

Species: Identified in past as S. morrisonii complex. These plants were called variant kruckebergii by Neilson (1977). We name this taxon S. brachiatus hoffmanii.

Dates visited: 1985: May 4, June 4, 27, August 11
1986: March 30, July 15
1987: July 6

Observations:

A small barren area adjacent to Bear Ridge Road near the B-Pad geothermal drilling site (Map 8). Area is surrounded by barbed wire fence with signs saying "BLM environmental area". Steam pipes were being installed along the road during July and August, 1985. The barrens extends along both sides of the road; primarily the south (downhill) side was sampled.

All plants at this site were small in stature in both 1985 and 1986, and appeared to be doing poorly, compared to other Streptanthus populations. Seed set was low, and there were no areas of concentration of plants. This is the only barrens that has been cut by a geothermal access road, which may have contributed to the low numbers observed.

Population size:

In March, 1986, less than 100 plants of all sizes were counted. Less than 100 were counted in 1987.

Area:

The surface area of this isolated barrens is 16 acres.

Study plots:

Susan Mazer study plots, 1985.

Samples taken:

Electrophoresis experiments were run on this population in 1986. Seeds were collected in 1986 and 1987. Several herbarium specimens have been collected.

Associated plants:

Associates include Allium falcifolium, Eriogonum viminea, and Eriogonum nervulosum on the barrens, and typical serpentine chaparral plants surrounding the site.

Ownership:

Federal (BLM) geothermal lease to Grace Geothermal Corporation.

Name: M-Site (KGRA)

Location: Mount St. Helena quad (R 8W, T 10N, Sec. 1)
Lake County

Species: Identified in past as S. morrisonii complex. We name this taxon S. brachiatus hoffmanii.

Dates visited: 1985: June 27, August 11
1986: Mar 30, May 5, June 25, July 15, Aug 30
1987: July 3, 5

Observations:

This site is reached via Bear Ridge Road east of the B-Pad and E-Pad, after the road starts descending the hill, heading towards M-Pad (Map 8). Many yellow-flowered plants are present on the top of the ridge.

From the top of the ridge, a very good view is presented of the isolated serpentine areas between here and Mount St. Helena. Buck Rock, a prominant outcrop of greywacke, is in clear view. Extensive sign of mountain lion is present on these barrens.

Population size:

The population size was estimated at a maximum of 500 adults for the entire serpentine barrens habitat.

Area:

This isolated barrens has a surface area of 20 acres.

Study plots:

A seedling survival plot was established in March, 1986 and the seedlings within the 1 m^2 area were counted on each subsequent visit in that year. Rosette survival over the summer was 50%.

Samples taken:

Seeds were collected in 1986 and 1987. Electrophoresis experiments were run on this population in 1986. Several collections were made for herbarium specimens.

Associated species:

The barrens are surrounded by a pygmy forest of Cupressus and Arctostaphylos of uniform height. Allium falcifolium and Eriogonum nervulosum are the major other plant species on the barrens.

Ownership

Federal geothermal lease to Grace Geothermal Corporation.

Name: Knoxville Recreation Area (Includes Hunting Creek, Rare Plant Canyon, and Dunnigan Hill). Other barrens within this area have been named in field notes and are illustrated on Map 9.

Location: Jericho Valley quad (R 5 W, T 11 N, Sec 14)
Lake County (near Napa County line)

Species: Identified in past as S. morrisonii. We name this taxon S. m. kruckebergii

Dates visited: 1985: February 6, April 25, June 8
1986: May 6, 31, July 10-15, August 30
1987: August 1

Observations:

Accessible from Devilshead Road off Knoxville-Berryessa Road. Many Streptanthus plants growing in this general area. Extensive ORV disturbance, including tracks through the center of a large Streptanthus stand.

A BLM funded study of the occurrence of Streptanthus morrisonii in this area was completed by Tierra Madre Consultants in 1986. The mapped distribution of all known populations is shown on Map 9.

Population size:

The estimated population size for this taxon over its entire range is greater than 100,000.

Area:

The barrens surface in the Knoxville area totals 120 acres. The plants occur on portions of four sections on 25 separate barrens. A line drawn around the major ridges to include most of the watershed encompasses 900 - 1,000 acres (Map 8).

Samples taken

Herbarium specimens have been made for many seedlings and for plants in full flower. Seeds from several locations within the Knoxville area were collected in 1986 and 1987. Electrophoresis experiments were run on this population in 1986.

Associated species:

All of the usual serpentine indicator plants are found in the Knoxville area, e.g. Pinus sabiniana, Quercus durata, Cupressus sargentii, and the rare Eriogonum nervulosum. Two other species of Streptanthus are present: Streptanthus breweri and S. hesperidis. Herbarium collections include:

Cedar Creek:
Phacelia corymbosa
Dechampsia caespitosa
Carex
Sanicula tuberosa
Allium falcifolium

Dunnigan Hill:
Eriogonum vimineum
Eriogonum nervulosum
Eriogonum ursinum
Streptanthus morrisonii kruckbergi

Name: Knoxville Recreation Area (cont).

Rare Plant Canyon:

Eriogonum vimineum
Eriophyllum lanatum
Zygadenus micranthus
Allium falcifolium
Juncus oxymeris
Deschampsia caespitosa
Chaenactis glabriuscula
Malacothrix floccifera
Arctostaphylos viscida
Lotus humistratus
Hesperolinon disjunctum
Eriogonum nudum
Ceanothus jepsonii
Gallium nuttallii
Phacelia corymbosa
Triteleia peduncularis

Hunting Creek:

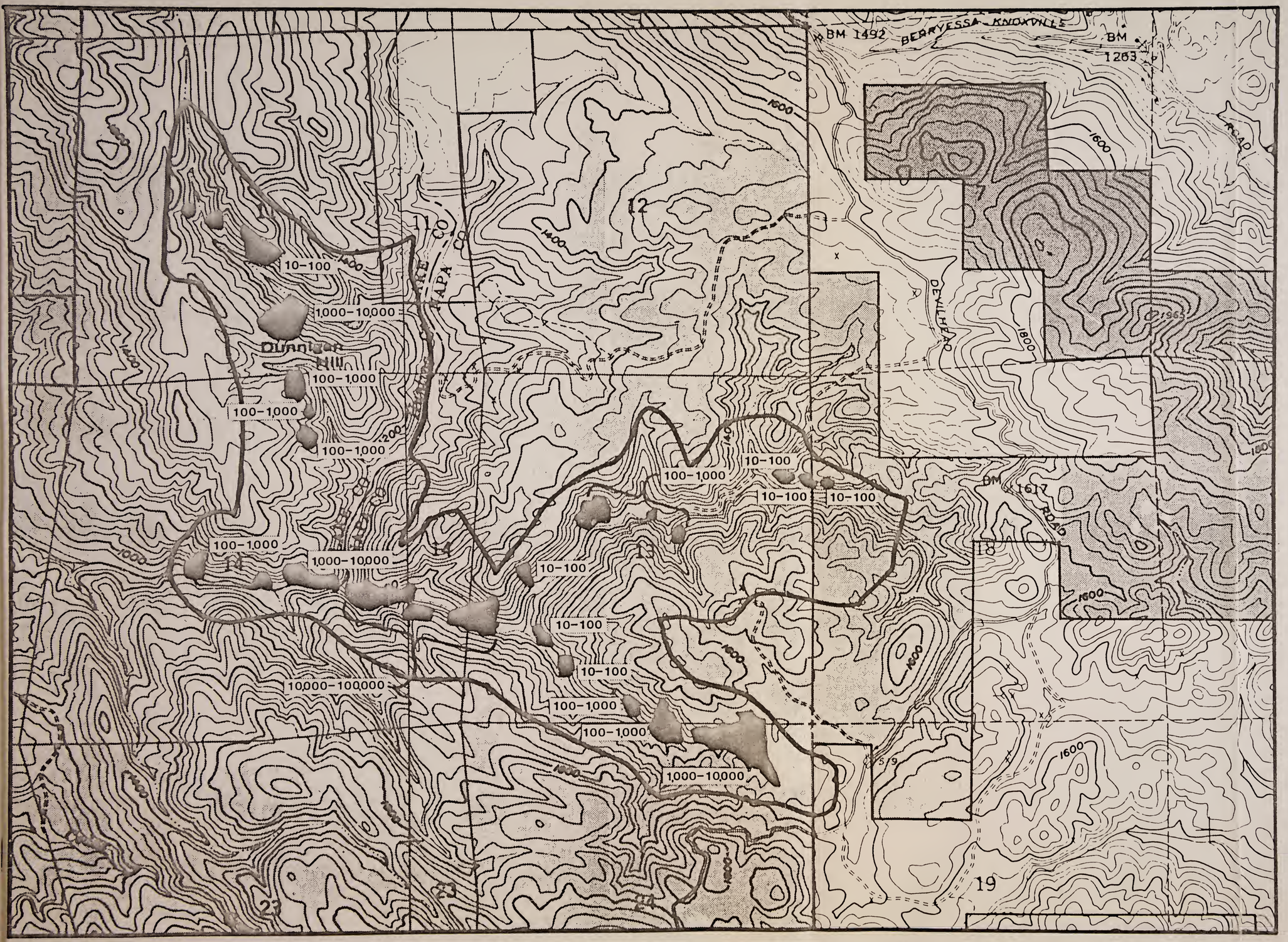
Aquilegia eximia
Eriogonum nudum
Grindelia camporum
Mentzelia laevicaulis
Cordylanthus pilosus ssp. diffusus
Calycanthus occidentalis

S. Tributary to Hunting Creek:

Balsamorhiza macrolepis
Trichostema laxum
Senecio clevelandii
Gallium pubens
Epilobium exaltatum
Castilleja stenantha

Ownership

Predominantly BLM, with a few inholdings of private ownership. Some of these are the Homestake Mining Company. All of the serpentine barrens containing Streptanthus morrisonii are on federal lands. See Map 9.



Bureau of Land Management
Ukiah District
Clear Lake Resource Area
Streptanthus morrisonii
kruckebergii

Map 9

10-100 Estimated Population of Morrison's Jewel Flower

Public Land

Recommended Preservation Zone

Serpentine Outcrops

N

Scale

0 1/2 Mile

Tierra Madre Consultants

Aug. 1986

Map Source: USGS Jericho Valley & Knoxville 7.5' Quads.

Other localities searched

Sites where Streptanthus morrisonii complex members were found

Burma Road - May 5, 1986, July 3, 1987. Neilson described a different form of S. morisonii (called variant stebbinsi) from two very small barren ridges in the chaparral on the east side of Burma Road. During a visit to this site in 1985, LaPre located only two stunted plants, and in 1986 he saw less than 10 plants and collected two. In 1987, the population was estimated at 10 - 100. This site is in Section 28, T 11N, R 8W. A Unocal drill rig was put in place near the access to the barrens in 1987. The population appears to be S. b. hoffmanii.

This barrens totals only about twenty acres in size, and is part of a State or federal geothermal lease.

The site should be preserved intact. A prescribed burn might increase the available habitat. Electrophoretic analysis of plants from this site would complement the existing data very well.

McKinley Road. This is a short road off Highway 175 leading to abandoned residential cabins. A barren surface is located about 1/2 mile to the east. Several plants belonging to the Streptanthus morrisonii complex were seen on July 5, 1987. Niall McCarten has visited this site. Ownership is private, belonging to G. Howard Peterson, Peterson Investment Company, P. O. Box 1998, San Leandro, CA 94577. The property is called the Diamond D Ranch. Jim Nelson has inspected these barrens and terms the area Harbin Ridge, which is a proposed site for the Geothermal Public Power Line route. These plants appear to be S. b. hoffmanii. The barrens area is 20 acres in size and the estimated population of plants at this site is 200.

Barrens in geothermal development area. Includes barrens west of Q Pad, barrens SW of NCPA #2. These were identified from aerial photos and then visited. All of these sites appear to be S. b. hoffmanii, based on the distribution, the purple stripe on the upper connate filaments, and the results of the electrophoresis experiments. The numbers and areas of these barrens are given below:

Estimated population size:
Barrens betwen M site and Buck Rock = Unknown, est. 100-1,000
NCPA #2 = 500 maximum
Wall Street Mine = Unknown, estimated 100 - 1,000
Callizo site = Unknown, estimated 10 - 100
Nelson site = Unknown, estimated 10 - 100

Area:
Barrens between RBQ and Davies Road = 4 acres
Barrens betwen M site and Buck Rock = 9 acres
NCPA #2 = 25 acres
Wall Street Mine = Estimated 25 acres
Callizo site = Unknown (estimated at 10 acres)
Nelson site = Unknown

Other localities (cont).

Bucksnort Creek - A small ridgetop barren is located off Butts Canyon Road on property of the Guenoc winery. Streptanthus morrisonii var. elatus was present in 1985 in very small numbers at this isolated location about five airline miles east of Three Peaks. No biennial Streptanthus were seen here in 1986 or 1987, however. Other serpentine indicator plants are also to be found, i.e. Allium falcifolium, Phacelia heterophylla, and Eriogonum vimineum. The size of this barrens is 15 acres and the estimated population in 1985 was less than 10, and none were seen in 1987.

Sites where Streptanthus morrisonii complex members were not searched for but are believed to be present

Layton Mine. Roger Raiche reports that this private parcel contains many Streptanthus morrisonii plants, and he may have collected some specimens and placed them in an herbarium. Access is through several locked gates. Permission to enter was denied to a BLM seasonal aide who wrote the owner.

Wall Street Mine. Access to this site is through locked gates. Seven locks were on the gate, which is on property of Anna Peterson. It would be possible to walk down to this area from the KGRA near the NCPA #3 plant. These plants are probably S. b. hoffmanii.

Callizo site in Napa County between Mount St. Helena and Wall Street Mine. Joe Callizo arranged to enter the area west of Mount St. Helena by contacting the Park Ranger at Robert Louis Stevenson State Park. He collected a few plants, which Kruckeberg identified as S. brachiatus.

Small barrens SW of Wardlow Rock. Jim Nelson accessed some isolated barrens in this area by helicopter and observed several Streptanthus. These are probably S. brachiatus hoffmanii, based on distribution.

Sites where Streptanthus morrisonii complex members were not found

Lake Berryessa - Several small barrens occur along the road between Lake Berryessa and Lower Lake. These were checked in 1985, and again on May 6, 1986. No Streptanthus were seen.

Colusa County - Near Stony Creek, Mendocino National Forest. Jim Nelson suggested a search of this area, since he had collected Streptanthus here in 1985. LaPre visited his collection site, the Mill Creek Campground, and other serpentine barrens along Stonyford Road near the Mendocino National Forest boundary in 1986. No S. morrisonii were seen, but S. breweri was collected. Another species, possibly S. hesperidis, may be present. Rebecca Dolan planted seeds from the Nelson collection, and reported that

Other localities searched (cont.)

the first leaves look different from S. morrisonii complex members. Herbarium specimens from this location include Eriophyllum lanatum, Monardella villosa, and Phacelia corymbosa, which were growing on a barrens along Stony Creek Road. This area was also checked in 1987, when LaPre camped at Fouts Springs on June 30 - July 1.

A trip was made to the Frenzel Creek Botanical Area and vicinity on June 30, 1987. S. breweri and S. glandulosa were collected, but no members of the S. morrisonii complex were detected.

Bartlett Springs Road - LaPre drove the length of this road in northeastern Lake County and southwestern Colusa County in May, 1986. Many S. hesperidis were present, but no S. morisonii were found. LaPre walked up to a barrens near the Indian Valley ACEC in 1987, but no biennial Streptanthus were located.

Morgan Valley Road - A barren was checked near the Napa/Lake county line in 1986 and 1987. No S. morrisonii were found, but S. breweri was collected.

Walker Ridge - In this area north of Clear Lake near the Colusa County line, we saw only S. hesperidis and S. breweri. A fairly extensive search near the Barrel Springs campground and the Walker Ridge Road between Bartlett Springs Road and the road to Indian Valley Reservoir failed to detect any Streptanthus morrisonii. Seeds of S. hesperidis were collected August 30, 1986 and in 1987 for future cultivation. This species can be compared electrophoretically with the S. morisonii complex members, perhaps shedding further light on speciation and relationships between subdivisions of the genus. The serpentine barren areas near Barrel Springs and along the Walker Ridge Road contained Allium falcifolium, Chloragallum sp., Cordylanthus sp., Quercus durata, Pinus sabiniana, Adenostoma fasciculata, Heteromeles arbutifolia, Cupressus mcnabiana, Cupressus sargentii, Arctostaphylos sp., and Eriodictyon trichocalyx. The area was also visited on June 30, 1987, and S. breweri was collected.

Mercuryville - September 2, 1986. This is an historic site for Streptanthus brachiatus, recorded on herbarium labels. Dolan and LaPre visited the small barrens in 1985 without locating any Streptanthus plants. Several other serpentine indicator plants were noted. The site was visited again by LaPre in 1987 without success.

2.6 miles N. Middletown on Highway 29 - This small barren along Highway 29, examined in 1985, did not contain any Streptanthus morrisonii and has been impacted by cattle grazing. Some serpentine indicator plants, such as Eriogonum vimineum and Phacelia heterophylla, were present, however, as were Allium fimbriatum, Arenaria douglasii, Gilia capitata, and Cryptantha hispidula.

Other localities searched (cont.)

Big Creek Road near Harbin Hot Springs. This small barren adjacent to the road was visited twice during July, 1987 and an annual species of Streptanthus was collected.

East Austin Creek outside Austin Creek State Recreation Area. A barren just outside the park boundaries to the north was visited on July 5, 1987. No Streptanthus were seen, though the barren contained Eriogonum vimineum, Phacelia heterophylla, and other serpentine indicators.

Cow Mountain area. A tour of this large region of serpentine chaparral was made on July 4, 1987. No biennial Streptanthus were detected.

Western Mine Road and Ida Clayton Road. On July 1, 1987, these roads were driven to look for access to other areas. A very small barren was located and searched without detecting any Streptanthus.

DWR Geothermal Plant sites near Bottle Rock Road. Serpentine chaparral was noted, but no barrens were seen near this site.

ANNOTATED BIBLIOGRAPHY

STREPTANTHUS MORRISONII COMPLEX

Babbel, G.R. and R.K. Selander. 1974. Genetic variability in edaphically restricted and widespread plant species. **Evolution** 28:619-630.

Allozymic variations in enzymes and other proteins as revealed through starch gel electrophoresis were used to examine the genic variability in local populations of pairs of species of Lupinus and Happlopapus in Texas in an attempt to study the relationship between genetic variability and ecological amplitude. One Happlopapus occurs on a variety of calcareous-clay soils, one is found on a similar variety of sandy loams. Levels of genetic variablity proved to be similar. In Lupinus, however, there is an inverse relationship between the level of genic variability and degree of edaphic restriction. Variability is greater in the species which occurs on prairie limestone, granitic, and sandy soils, than in the edaphically restricted species which grows well only on sandy soils. The results from Lupinus are consistent with the niche-width hypothesis. However, the evidence that levels of genic variability reflect different evolved adaptive strategies for exploiting different ranges of environmental heterogeneity may be equivocal because variation in the edaphically restricted species could have been reduced by a recent bottleneck.

Brooks, R.R. 1987. **Serpentine and its vegetation: a multidisciplinary approach.** Ecology, phytogeograpy, and physiology series, Vol. 1. Dioscorides Press, Portland, Oregon.

This book has just been released and was not received in time to include in this bibliography. A review by Kruckeberg in is the October 1987 issue of **Fremontia** (Vol. 15, No.3).

Brooks, R.R., S. Shaw, and A.A. Marfil. 1981. Some observations on the ecology, metal uptake and nickel tolerance of Alyssum serpyllifolium subspecies from the Iberian peninsula. **Vegetatio** 45:183-188.

Experiments were carried out on the tolerance to, and uptake of, nickel by three Iberian subspecies of Alyssum serpyllifolium. Serpentine endemics were found to be hyperaccumulators of nickel while a probable non-serpentine ancestor was not. Plants will tolerate higher nickel levels in the soil when excess calcium is added. This was apparently achieved by lowering the uptake of

nickel. There appeared to be a concommitant decrease in calcium uptake and an increase in magnesium. Resultant lower calcium/magnesium ratios result from a mechanism which renders nickel innocuous at the expense of calcium uptake. Based on physiological characters, this study suggests upgrading the subspecies status of the two serpentine taxa studied here to species rank.

Buck, L.J. 1949. Associations of plants and minerals. **Journal of the New York Botanical Garden** 50:265-269.

Early paper noting how distinctive plant communities can reveal information about underlying soil characteristics and geology. This is the concept of indicator species and is suggested as potentially useful for locating areas for mine exploration.

Crane, N. and Malloch, B. 1985. A rare plant study for the Geysers-Calistoga KGRA. Produced by Pacific Gas and Electric Company.

This report contains a thorough presentation of the distribution of **Streptanthus brachiatus** and **S. morrisonii** in the KGRA. The taxonomy of the group to date is reviewed and species associated are reported. The results of several years of field surveys are summarized on topo maps which also show historical occurrences.

Callizo, J. and J. Ruygt. 1984. Cedar Roughs. **Fremontia** 12(1):17-18.

Description of the vegetation on serpentine soils in the Cedar Roughs area west of Lake Berryessa in Napa County. This area is 7,000 acres large comprised mostly of serpentine rocks and soil. Five thousand acres is in cypress forest (Cupressus sargentii) with few other vascular plants present. Cedar Roughs is generally pristine with no roads. It has been designated a Wilderness Study Area by the Bureau of Land Management and has been proposed as an Area of Critical Environmental Concern which would provide it with further protection. Almost all the land is publicly owned. There is no mention of members of the Streptanthus morrisonii complex.

D'Appolonia, 1982. Homestake Mining Company McLaughlin Project Environmental Impact Report. Appendix 9, Vegetation Resources. Report prepared for the Lake and Napa counties Planning Departments, Lakeport and Napa, CA.

This report, authored by Glenn Clifton, is a very complete review of the flora and vegetation of the Knoxville area, particularly the site of the McLaughlin Gold MIne. Extensive field studies included many of the barrens on BLM lands in the Knoxville Recreation Area, where Streptanthus morrisonii was located. Detailed descriptions are provided of new localities for several species of rare plants, most associated with serpentine barrens or serpentine chaparral. This report is the most extensive review of the flora of this area available, containing specific habitat and niche classifications of the limited distribution flora, along with reviews of the status of each species. As a result of these studies, many taxa have been discovered to be more common than previously believed. All biennial Streptanthus are assigned to S. morrisonii or to the S. morrisonii complex.

Fowler, R. and J.A. Brownell. 1981. The Geysers biological resources mapping project. Staff report, California Energy Commission.

Maps biological resources of the KGRA on 7.5 minute USGS topographic maps. This data is from records checks only and no new field work was done. The Whipering Pines and Mt. St. Helena maps show locations for Streptanthus morrisonii. The Geysers quad shows locations for S. morrisonii and S. brachiatus.

Gankin, R. and J. Major. 1964. Arctostaphylos myrtifolia, its biology and relationship to the problem of endemism. **Ecology** 45:792-808.

This paper contains a lengthy review of papers which support the theory that many cases of disjunct plant distribution can be related to regionally particular soil parent materials whose evident effect is to exclude the regionally complex vegetation. With competition by zonal vegetation thus weakened, disjunct plants can and do occur. The vegetation associated with A. myrifolia is poor, mostly annual, and adapted to acid, seasonally wet sites. Historical factors of some kind, and not the contemporaneously acting ecological factors alone, are assumed to help account for the limited distribution of the species.

Gottlieb, L.D. 1973. Enzyme differentiation and phylogeny in Clarkia franciscana, C. rubicunda, and C. amoena. **Evolution** 27:205-214.

A study of three closely related Clarkia species with similar morphology but very low fertility of hybrids due to meiotic irregularities attributed to gross chromosomal structrual differences. C. franciscana consists of a single population on a serpentine outcrop. Rapid speciation due to chromosomal repatterning and resultant reproductive isolation was proposed for the taxa. However, electrophoretic evidence showed the proposed progenitor and derivative species are not very similar. Although such an evolutionary scenario can not be ruled out based purely on this electrophoretic data, it is suggested that a greater genetic similarity should be found before evolutionary relationships are hypothesized from such analyses.

Hanes, T. 1977. Chaparral types. In Barbour, M.L. and J. Major, Terrestrial Vegetation of California. Wiley. New York, NY.

This chapter contains a discussion of the characteristics of serpentine chaparral flora.

Hoffman, F.W. 1952. Studies in Streptanthus. A new Streptanthus complex in California. **Madrono** 5:189-220.

This is the original paper which describes Streptanthus brachiatus and S. morrisonii with its three subspecies. All are in the subgenus Euclisia. The type localities (areas first collected) are in Sonoma County for S. morrisonii subspecies morrisonii and hirtiflorus. Subspecies elatus was found near what is now Robert Louis Stevenson State Park on the Lake - Napa County line. The type locality for S. brachiatus is on the KGRA near Socrates Mine. All members of the complex are glabrous and glaucous with seeds usually wingless or with a suggestion of a wing. Juvenile leaves are cabbage-like in texture, broad, palmately lobed, dentate or serrate, with the upper surface usually mottled. At the time of this work little was known of the flora of the Geysers area, access was difficult, and new, undescribed taxa were frequently being encountered.

Streptanthus morrisonii ssp. morrisonii and ssp. elatus have several traits in common and in contrast to the other two taxa in the complex despite being separated by a fairly great distance. Both have greenish-yellow to golden-yellow calyces (occasionally purplish) and upper connate filaments without longitudinal colored lines. Subspecies morrisonii has juvenile and lower

leaves with uniformly green upper and lower surfaces. The upper connate filaments are uniformly orange or orange-yellow. This taxa is endemic to the serpentines of Big and East Austin Creeks and their tributaries. Subspecies elatus has juvenile and lower leaves with heavily mottled (purple-brown) upper surfaces and uniformly purplish lower surfaces. Upper connate filaments are uniformly yellow. This taxa is endemic to serpentines on the headwaters of St. Helena and Bucksnort Creeks in Lake County. Collections were made at several populations for both of these taxa by Hoffman but all sites for a given taxon were within one mile of each other.

Streptanthus morrisonii ssp. hirtiflorus and S. brachiatus both have purple or rose colored calyces (never yellow) and upper connate filaments with two purple longitudinal lines. Subspecies hirtiflorus has a calyx which is non-recticulate and densely hirsute with long hairs. These plants are endemic to serpentines on the headwaters of East Austin Creek, Sonoma County. S. brachiatus has glabrous, reticulate calyces and is endemic to serpentines east of Pine Flat, on the Sonoma-Lake County line.

Hoffman based his classification on morphological observations of fresh and pressed material and grew seedlings of each taxa in order to study shape, color, and texture of the crucial juvenile leaves. His paper contains drawings of all the taxa with all life history stages represented.

Koenigs, R.L., W.A. Williams, and M.B. Jones. 1982. Factors affecting vegetation on a serpentine soil. I. Principal components analysis of vegetation data. **Hilgardia** 50: 1-14.

Vegetation of 40 sample stands on serpentine soil (weathered, not outcrops) in the Lake Berryessa watershed was analyzed and used to indicate conditions which might be limiting establishment of annual species used for livestock grazing.

Koenigs, R.L., W.A. Williams, M.B. Jones, and A. Wallace. 1982. Factors affecting vegetation on a serpentine soil. II. Chemical composition of foliage and soil. **Hilgardia** 50: 15-25.

Ion concentrations in the foliage of Adenostoma fasciculatum, Arctostaphylos viscida, Cupressus sargentii, and Quercus durata were determined for plants growing in the Lake Barryessa watershed and correlated with the abundance and plant size of these indigenous species and with soil concentrations of these ions. The species differed most in calcium concentration. Those

species apparently most adapted for life on serpentine soils possessed average Ca/Mg ratios in the leaves which were very much higher than those in the soil. There was no evidence of toxicity to nickel, chromium, or cobalt. These analyses were used to determine which species are indicative of soil conditions which would be most favorable to introduced, non-serpentine tolerant species used for livestock grazing.

Kruckeberg, A.R. 1950. Intraspecific variability in the response of certain native plant species to serpentine soil. **American Journal of Botany** 33:408-419.

This is Dr. Kruckeberg's dissertation work. At the time it was published little was known about the ecology, genetics, and evolution of taxa growing on serpentine or what their relationship was to non-serpentine taxa. It is still an often cited work. Based on studies of distribution and serpentine tolerance, Kruckeberg puts forth the hypothesis that members of the subgenus Euclisia (particularly Streptanthus glandulosus) represent 'depleted' taxa which were once widespread on many soil types but which are now restricted, perhaps due to low competitive ability, to serpentine. Supporting this view is the fact that most members of this group are obligate serpentine endemics but a few subspecies are facultative. In contrast, 'insular' species are those which have developed in isolated islands of habitat. It is possible that, once restricted to serpentine, members of the subgenus Euclisia are now undergoing insular-type evolution. With his common garden experiments, Kruckeberg demonstrated that populations of the same species which grow on and off serpentine are genetically different soil races or edaphic ecotypes.

Kruckeberg, A.R. 1954. The ecology of serpentine soil. III. Plant species in relation to serpentine soils. **Ecology** 35:267-274.

This paper addresses why some plants cannot grow on serpentine soils, why some can grow on and off, and why some are completely resticted to serpentine. Tolerance to low calcium levels seems to be the principal adaptation required to grow on serpentine. In most cases populations on serpentine are ecotypically distinct from those on non-serpentine. All three degrees of tolerance appear in Streptanthus. Serpentine plants may be restricted to serpentine by intolerance of more rigorous competition in non-serpentine plant communities. Therefore, edaphic factors on the one hand, and biotic or dynamic factors on the other, may produce sharp discontinuities between serpentine and non-serpentine vegetation.

Kruckeberg, A.R. 1956. Variability in fertility of hybrids between isolated populations of the serpentine species, Streptanthus glandulosus Hook. **Evolution** 11:185-211.

Populations of the annual crucifer Streptanthus glandulosus are largely restricted to the discontinuous outcrops of serpentine in California. Many of the partially isolated serpentine habitats support morphologically distinguishable strains of the species complex. Such polymorphism has led taxonomists to recognize no less than 12 species. More conservative treatments, however, define the complex taxonomically as one or two species with several infraspecific taxa. To determine the extent of genetic isolation among various strains, a program of hybridization involving 32 different strains of the complex in over 300 combinations was undertaken. Significant differences were found in the pollen fertility of the interstrain hybrids. The complex was found to consist of three genetically isolated elements (= species), one with 3 subspecies. A significant inverse correlation was found between the degree of hybrid fertility and the distance in miles separating the two parents. This trend often transgressed subspecific boundaries. These data support the hypothesis that the present distribution pattern has resulted from biotype depletion. It could not be determined if the barrier to gene exchange between certain populations is the result of random fixation, selection, or a combination of these two evolutionary mechanisms. Additionally, several points germaine to the S. morrisonii complex were made: 1) barriers to selfing are found in all members of the subgenus Euclisia except S. niger which involve protandry in which the anthers grow away from the stigma by the time of complete anthesis; 2) high pollen fertility of hybrids between strains with similar flower color from the same geographic province is the cohesive element which binds populations of Streptanthus into taxa of varying levels for Kruckeberg and Hoffman's study.

Kruckeberg, A.R. 1958. The taxonomy of the species complex, Streptanthus glandulosus Hook. **Madrono** 14: 217-227.

A review of the taxonomy of Streptanthus glandulosus complex (previously recognized as at least 5 different species) based on data collected during an experimental study (Kruckeberg, 1956). This study of genetic isolation between populations revealed complete isolation between some, partial between others. This isolation correlated with geographic and morphological distinctness. The S. glandulosus complex was resolved into three species, one with three subspecies. For the complex taxa, interfertility data is often in conflict with distinctions based on morphological characters. The following paraphrased paragraph may be of particular pertinence to the study of the S. morrisonii complex: A key to the five taxa permits the identification of

the majority of populations. It must be recognized that an intricate pattern of variation that appears to be correlated with the spatial isolation of populations is present. In other words, the discontinuity of suitable habitats has prompted many morphologically distinct populations of a very local occurrence. Thus the eternal dilemma is forced upon systematic botantists of either having to recognize taxonomically each Mendelian population or abstracting from the total variation pattern only the more salient representations. The latter course has been adopted here as best serving the needs of practical taxonomy. At the same time attention is called to the fact that certain taxa (subspecies) encompass populations with variable morphology and varying degrees of genetic isolation.

Kruckeberg, A.R. 1967. Ecotypic response to ultramafic soils by some plant species of northwestern United States. Brittonia 19:133-151.

A comparison of the growth characteristics in greenhouse and common garden experiments of endemics and wide-ranging species which grow on ultramafic (= ultrabasic) rocks (serpentine, peridotite, and dunite). Herbaceous perennials showed the clearest ecotypic response. Woody species showed only slight ecotypic response or delayed the expression of their genotypic adaptability. Where ultramafic abut non-ultramafic soils, those populations of wide-ranging but edaphically indifferent species that grow in non-ultramafic habitats can have a significant proportion of individuals tolerant to ferromagnesium soils. This suggests gene flow between populations of contrasting edaphic sites and possibly preadaptation for the ultramafic habitat. Strains of two introduced weeds have become ecotypically tolerant to ultramafic soils, probably within the last 75 years.

Kruckeberg, A.R. 1969. Soil diversity and the distribution of plants, with examples from Western North America. **Madrono** 20:129-154.

General discussion of how soil type can influence plant distribution, including a section on serpentine. Three physiographic regions with abundant serpentine are defined: the Central Coast Ranges, the Klamath-Siskiyou Area, and the Northern Cascades-Wenatchee Mts. Area. For the North Bay Counties, serpentine soils stand in sharp contrast to adajent non-serpentine sites which largely support wide-ranging woody dominants of the oak woodland, mixed conifer, or chaparral plant community. Indicators of serpentine soils in this region are sclerophyllous shrubs and small coniferous trees :Quercus durata, Ceonothus jepsonii, Garrya congdonii, Cupressus sargentii, and Cupressus macnabiana.

Kruckeberg, A.R. 1977. Rare plant status report on Streptanthus morrisonii ssp. hirtiflorus. California Native Plant Society, mimeo.

Distribution and description of this subspecies. Endangerment factors are stated as unknown but the limited distribution of this taxa is pointed out. Management suggestions state the need for current field studies. This status report was most likely prepared in response to early federal proposals for listing of this species as threatened. It is currently a candidate for protection.

Kruckeberg, A.R. 1984. California's serpentine. **Fremontia** 11(4):11-17.

A good, thorough, general discussion of the origin, distribution and characteristics of serpentine in California. A distribution map of serpentines in the state is provided. These serpentine soils are derrived from igneous rock and are generally low in calcium, nitrogen, phosphorus, and potassium and high in nickel, cobalt, and chromium. They are also high in magnesium and iron which places them in the class of rocks called ultramafic. These soils are also low in the trace mineral molybdenum. Woody plants growing on serpentine are stunted or compact and herbaceous plants are often dwarfed. Leaves are reduced, tough, and narrow with glaucous 'bloom' or pubescence and are frequently anthocyanous purple. Some are hyperaccumulators of nickel. Floristically, the vegetation on serpentine is usually distinct from that on surrounding soil types and composed of fewer species.

Kruckeberg, A.R. 1984. The flora on California's serpentine. **Fremontia** 12(1):3-10.

A discussion of serpentine vegetation in California by geographic area. A discussion of the various theories of how such a demanding habitat as serpentine managed to foster the evolution of a rich and diverse flora is included. There are two types of restriction to serpentine, relictual (e.g. Cupressus sargentii, Quercus durata) and species of recent origin, usually herbaceous species (e.g. Hesperolinon, Navarretia, Streptanthus). But fixing an age on a taxon does not explain how it evolved from some ancestor. Two models are presented: 1) gradual divergence of widespread species through races with genetically fixed tolerance to serpentine and 2) catastrophic selection in which, during times of extreme stress, all but a few individuals of a species may be eliminated (the survivors having a singular genetic makeup that both isolates them from nearest relatives and

makes them sucessful survivors on serpentine). Threats to preservation of this unique flora are discussed. Old threats were principally associated with mining activities. Modern threats include geothermal resource developement, nickel and gold mining, livestock grazing, timber harvesting, and off-road vehicles. Some areas are currently being protected by 'benign neglect'. The rest of this issue of **Fremontia** contains descriptions of specific serpentine floras in California by various authors.

Kruckeberg, A.R. 1984. California serpentines: flora, vegetation, geology, soils, and management problems. University of California Press, Berkeley.

This book is a compilation of Kruckeberg's extensive work on serpentine flora and ecology. It has a focus on management concerns and provides a good review of what is known about geology, physiological ecology, evolutionary biology, and floristics of California's serpentine plant communities. Sections deal specifically with the large number of endemics found in the Napa-Lake-Sonoma County regions and Streptanthus is used to illustrate the range of habitat specificity that can exist in a genus.

Kruckeberg, A.R. 1987. `Serpentine endemism and rarity'. In: **Conservation and management of rare and endangered plants.** Proceedings of a California conference on the conservation and management of rare plants. Editor: T.S. Elias. California Native Plant Society. Sacramento, CA.

Kruckeberg reviews the unique physiognomy of serpentine species and uses the genus Streptanthus as an example of how narrow serpentine endemism may have developed over evolutionary time. He also reviews threats to the preservation of flora on serpentine.

Kruckeberg, A.R. and J.L. Morrison. 1983. New Streptanthus taxa (Cruciferae) from California. **Madrono** 30:230-244.

Two California serpentine endemics, one from the North Coast Ranges (Tehama to Trinity Counties), and one from western Merced County are described. Five new sections in Streptanthus, subgenus Euclisia, which has a high incidence of narrowly endemic serpentine outcrop taxa, are also described. Salient features of this subgenus include zygomorphic flowers, non-bracteate

inflorescences, and filaments with 1 or 2 pairs of stamens usually reduced to vestigial and sterile anthers. Streptanthus morrisonii and S. brachiatus are the only taxa assigned to the Section Biennes This paper notes that a recent study (Neilson, 1977) suggests the presence of interpopulation variation in the S. morrisonii complex and suggests Hoffman's taxonomy may have to be modified.

Kruckeberg, A.R. and D. Rabinowitz. 1985. Biological aspects of endemism in higher plants. Annual Review of Ecology and Systematics. 16:447-479.

This paper reviews historical ideas on the nature of plant endemism and rarity and discusses the roles of environment, genetics, and phytogeographic history in determining the rarity and habitat specificity of species. The conclusion is reached that there are several types of rarity and that many factors contribute to the abundance of species. Generalizations concerning, for example, the role of limited genetic variation in determining the geographic distribution of plants can not be made.

Kruckeberg, A.R., Rodman, J.E., and R.D. Worthington. 1982. Natural hybridization between Streptanthus arizonicus and S. carinatus (Cruciferae). **Systematic Botany** 7:291-299.

A study of natural hybridization between these two species of Streptanthus concludes that the species are conspecific. Data used came from field studies of natural hybrids (normal meiosis and pollen), chemical studies of the similarities of glucosinulates of purported parents and hybrids, and the reconstitution of fertile hybrids in the greenhouse. This is the first known occurrence of natural hybridization in the genus.

Lewis, H. 1962. Catastrophic selection as a factor in speciation. **Evolution** 16:257-271.

Based on observations from his studies of Clarkia (Onagraceae), Lewis found that speciation at the diploid level ordinarily involves a rapid reorganization of the genome associated with ecological differentiation. The sudden extinction of peripheral populations with the survival of one or two 'resistant' individuals (based on some physiological difference) is catastrophic selection. It is believed that extinction of peripherals is common but survival and reproduction of

'resistant' is rare. This process results in immediate spatial isolation of survivors and progeny. However, if there is no barrier to gene flow (such as chromosomal rearrangement) in the derived population, the parental population may move back in and absorb the varients and restore the gene norm. For Clarkia Lewis also concludes that ecological races do not seem to represent a stage in the normal speciation process. No pairs of closely related diploid organisms seem to have had such an origin. Also for Clarkia, derivatives are always found in more xeric habitats which is an example of unidirectional adaptation.

Mason, H.L. 1946. The edaphic factor in narrow endemism. I. The nature of environmental influences. **Madrono** 8:209-257.

A somewhat dated paper which explores the relationship of limiting factors of physical tolerance and edaphic endemism. Each species will occupy locally the same size and configuration of area as do the enviromental conditions to which it is adapted and age of the species has nothing to do with it. Theories of types of endemism are discussed.

Mason, H.L. 1946. The edaphic factor in narrow endemism. II. The geographic occurrence of plants of highly restricted patterns of distributions. **Madrono** 8:241-257.

This paper discusses the great concentration of endemics in the Napa-Lake area due to the great edaphic diversity present (volcanics, serpentines, vernal pools). Streptanthus, Navarretia, Linum, and Astragalus are mentioned as genera in which speciation has involved selective elaboration over the edaphic environment.

Mazer, S.J. 1985. The population biology of Streptanthus morrisonii (Brassicaceae) in the vicinity of the N.C.P.A. geothermal site #3 (Socrates Mine Road-Ridge Road; Middleton, California). Report submitted to the California Energy Commission, Siting and Environmental Division, Sacramento, California.

A two year demographic study of three populations of Streptanthus morrisonii on the serpentine barrens within a 1,000 meter radius of the Northern California Power Agency's geothermal site. This species is characterized as a morhologically and phenologically (based on flowering time) diverse taxon. It's distribution on barrens is patchy, appears to be influenced by steepness,

coarseness of the soil, and availability of water. It is fairly abundant and uniformly distributed in open areas in full sun where there is no competition from other plants. Seeds tend to be washed downhill on slopes greater than 40 degrees. Plants are found in low densities on the margins of barrens interspersed with Arctostaphylos and Cupressus. There does not appear to be much seed dispersal between sites. The plants were found to be not strictly biennial, since some flower the first year and some will flower during their second and third year. Much beetle damage was seen on flowers and fruits. S. morrisonii is pollinated by honey bees and bumblebees and does not self-pollinate without insect assistance. Differences in size and branching habit and pubescence of calyces were found between the three populations, as were demographic and phenological differences. Population size in permanent quatrats was declining but local fluctuation in numbers seems to be characteristic of the taxon. Soil particle size affected seedling survival in greenhouse experiments: plants grew better in coarse than fine soil. Artificial crosses demonstrated in the greenhouse that seeds produced by selfing were smaller and had lower rates of survivorship and growth than did seeds produced by outcrosssing.

Morrison, J.L. 1938. Studies in the genus Streptanthus Nutt. I. Two new species in the section Euclisia Nutt. **Madrono** 4:204-209.

Publication of descriptions of 2 new species from Morrison's dissertation on the subgenus Euclisia (some authors now treat this taxon as a section), Streptanthus batrachopus from Marin County and S. callistus from Santa Clara County.

Morrison, J.L. 1941. A monograph of the section Euclisia Nutt., of Streptanthus Nutt. PhD dissertation, University of California, Berkeley. 102 pp.

This work describes 4 subsections comprised of 6 species with a total of 6 subspecies. Two of these species are newly described. This work was carried out prior to the discovery of the S. morrisonii complex. Consideration is given to the problem of serpentine endemism which seems to have played a large part in the development of the entities making up this section. Only 4 of the 16 are found on non-serpentine soils. Cytological studies of three of the species found n = 14. In related sections, n = 7. Distribution maps of the range of each taxon and illustrations (photos of type specimens) are included. Most members of this section, which is distributed from San Luis Obispo County to southern Oregon (all taxa are found in the Coast Ranges except one in the Sierra Nevada), are rarely collected.

The problem of relating these very local endemics to the more widespread species in the section is a real one. It is difficult to believe that any species in a genus presumably as recent as Streptanthus can be restricted to a single slope or to only 1 or 2 isolated ridges'. Existence of large numbers of local endemics might mean that this is an old group persisting only in a few localities but when local endemism is correlated with edaphic factors and bizarre floral morphologies, these endemics represent not relics, but a relatively recent development in a comlex, rapidly evolving group whose chief characteristic is intolerance to non-serpentine soils. It was hoped that more collecting would help reveal the relationships between the taxa. It is additionally noted that these plants grow best in conditions of low magnesium but not in pH's lower than 7.8; these plants require very basic soils. Seeds germinate soon after the first rains of winter and seedlings grow gradually for several months.

Munz, P.K. and D.D. Keck. 1973. **A California flora and supplements**. University of California Press. Berkeley, CA. 1681 pp.

This most up-to-date flora for northern California contains the taxonomy of the Streptanthus morrisonii complex as delineated by Hoffman in the Supplement. This the first flora of the region to elevate Caulanthus to genus level. It had previously been treated as a subgenus of Streptanthus. Caulanthus does not occur principally on serpentine outcrops.

Muth, G. 1984. Napa County flora: reports. Pacific Union College, Angwin, CA.

Extensive computer records of specimens in the PUC herbarium giving data on characteristics of collection sites and associated species. Locations are mapped on facsimiles of 7.5 minute USGS topographic maps. Eleven collection sites for Streptanthus morrisonii are recorded.

Neilson, J.A. 1977. Observations on populations of the Streptanthus morrisonii complex in the central and southern Mayacmas Mts., Lake, Sonoma, and Napa Counties California. Report to Shell Oil Company by Ecoview Environmental Consultants.

This paper presents the results of a study to establish the distribution of and variation among Streptanthus tentatively assigned to S. morrisonii. The project was also initiated to

determine to what extent S. brachiatus is rare and to infer the impact of a narrow road across a population in the Southern Mayacmas Mountains in Lake, Napa, and Sonoma Counties. Twenty-nine populations were discovered and examined ecologically and taxonomically. Four significant previously undescribed variants were found in geographically distinct areas. These variants differ from described taxa in branching habit, flower color, and vascular traces on the stamen filaments. The study concluded the taxon in question in the way of road construction was not S. brachiatus and that this taxon has other populations and would not be significantly impacted by the construction. Further studies were stated to be underway. Notes were included on the ecology and growth parameters of the taxon. It is found on serpentine parent material giving rise to Huse Stoney Loam soil primarily on gravelly surfaces with large boulders and little shrub litter. Ninety percent of all barrens surveyed had plants in the Cobb Mountain - Oat Hill area. Seventy percent of populations were associated with local landslides or areas disturbed by grading but plants did not grow on tailings or fresh exposures, implying the need for some weathering. Density rarely exceeds 4 plants per square meter. Most common slopes were 15 - 60% and most common exposures were south to southeast. Seeds appear to have no specializations for dispersal but they may roll downhill. Populations were often associated with ridge tops and talus slopes but were also found on the lower reaches of talus where sites are most stable. A minimum barren size of 40 feet across seemed to be necessary. Plant associates were the falcate-leaved onion (Allium falcifolium), squirrel-tail grass (Sitanion hystrix) and cliffbreak (Onychium densum). Two populations of S. brachiatus which had been previously described were located but no new sites were found. Little variation was found in these populations and plants were uniform in flower color, branching habit, lack of pubescence on sepals, and stamen characteristics. Revegetation potential was stated to be fairly high by transplantation of nursery grown seedlings and by stockpiling or spreading of topsoil with its natural seed load.

Osterling, R.S. 1979. Rare and/or endangered plants located along the right-of-ways and well location CA 956-4 Lake County, California. Report submitted to Aminiol USA, Inc.

Field surveys were made on March 9, 1979 to determine if a short crossing of serpentine material by a road would impact any plants of the Streptanthus morrisonii complex. Not much disturbance was found and no complex members were seen. A map is included.

Osterling, R.S. 1980. Rare plant survey on proposed Occidental geothermal plantsite. Prepared for Stone & Webster Engineers, Denver, Colorado.

Field surveys made on June 16, 1980 found Streptanthus brewerii and S. glandulosus but no S. morrisonii, although it has been reported from the leasehold area. Suitable habitat, however, was found. A map of the study area is included.

Osterling, R.S. No date. Rare plant survey on Aminoil Federal Lease Units 7, 8 & 10. Prepared for Aminoil USA, Inc.

Field surveys made during mid-June, 1979 found suitable habitat for Streptanthus morrisonii but found only S. brewerii, an annual on the study area. Neilson (1977) recorded S. morrisonii for this area. This report points out the confusion in the status of Streptanthus in the Geysers area.

Osterling, R.S. No date. Rare plant survey on Sacramento Municipal Utilities District geothermal Unit 1 plantsite and one mile zone of influence. Prepared for Stone & Webster Engineers, Denver, Colorado.

Field surveys were made on June 16, 1980. No members of the Streptanthus morrisonii complex were found but suitable barrens were present.

Proctor, J., W.R. Johnson, D.A. Cottam, and A.B. Wilson. 1981. Field-capacity water extracts from serpentine soils. **Nature** 294:245-246.

A study of the characteristics of water solutions from serpentine soils from Scotland and Zimbabwe. Previous studies have analyzed soil rather than water solutions which are what a plant really interacts with. Their results show low calcium levels can exacerbate magnesium toxicity and therefore be a factor limiting plant growth in some soils, nickel is likely to be toxic, and that nutrient concentrations are not always low in serpentine soils as often proposed.

Proctor, J. and S.R.J. Woodell. 1975. The ecology of serpentine soils. **Advances in Ecological Research** 9:255-366.

Thorough review article focusing on the geology of serpentine and the results of studies into the influence of the unusual mineral composition of this parent material on vegetation. Contains a short section on the animals, fungi, and bacteria found on serpentine soils. Evolution on serpentine is reviewed in sections on ecotypic differentiation, endemics, plants showing disjunct distributions on serpentine, morphological differences, and speciation processes. It is noted that characteristic features of serpentine plants which make them appear xeromorphic may actually be the result of low tissue production due to low levels of nutrients. Kruckeberg's theories of the origin of endemics are reviewed and the authors state a preference for the idea that insular species are most likely to have developed from wide-ranging species which came into contact with several serpentine outcrops and developed different races, which eventually become established as endemics. Alternatively, those endemics may have developed through dispersal of an already established endemic to other outcrops.

Raven, P.H. 1964. Catastrophic selection and edaphic endemism. **Evolution** 19:336-338.

Response to Lewis (1962) above, with particular reference to the extreme endemism found in the California flora. Raven sees a direct connection between catastrophic selection and edaphic endemism. Many populations of local endemics are found in open stands on soil types unusual for the species as a whole. These populations are most likely to undergo severe selection pressure and drastic reductions in numbers and therefore to be fixed at adaptive modes different from the main body of the species. With subsequent genotype reorganization, these incipient species may then become narrow edaphic endemics. The paper reports such a phenomemon could explain the pattern of variation found in the Streptanthus glandulosus complex (see Kruckeberg, 1957) which consists of extensive clusters of narrow endemics. Raven feels past explanations for this sort of distribution are manifestly incomplete.

Raven, P.H. and D.I. Axelrod. 1977. Origin and relationships of the California flora. **University of California Publications in Botany** 72:1-34.

This paper contains a section on edaphic endemism throughout the state and dicusses serpentine soils. It states that many taxa seem to have originated as serpentine endemics by saltation speciation (catastrophic selection and/or biotype depletion).

They propose the following scenario: some present taxa had a wide occurrence on non-serpentine sites from the Miocene well into the late Pliocene, that they invaded serpentine sites as these became available in the Pliocene, and that they were later confined to serpentine areas as the more widespread ecotypes disappeared as summer rains decreased. Adaptation to ultrabasic substrates removes them from competition with the adjacent, non-serpentine flora. These ideas are based on the age of serpentine rocks and the time they have been exposed for plant occupation, the degree of restriction, climate, and the nature of plant evolution. This paper mentions Kruckeberg's (1956) study of Streptanthus species which found a significant correlation between the degree of hybrid fertility and the distance separating the two parents, which suggests a pattern of increasing restriction to serpentine and biotype depletion. It is pointed out that increasing adaptation to serpentine soils need not necessarily be thought of as biotype depletion. The patterns that are observed would originate automatically if serpentine afforded one of the few available habitats for the group and the plants were able to grow there. The point is also made that moisture may be factor in the persistence of relictual taxa on serpentine. The authors contend that serpentine soils are not as dry as popular opinion would have. This is a very easy-reading and thorough discussion.

Reeves, R.D., R.R. Brooks, and T.R. Dudley. 1983. Uptake of nickel by species of Alyssum, Bornmuellera, and other genera of Old World tribe Alysseae. **Taxon** 32:184-192.

This paper reports the results of a survey of the Old World Alysseae which grow on serpentine soils as part of a larger study tracking the existence of nickel hyperaccumulors in the Brassicaceae. Although adaptations to unfavorable edaphic factors can take place quickly, all nickel hyperaccumulators studied here are from regions beyond the maximum advance of Pleistocene ice-caps. Therefore, these plants may exhibit characteristics which began to evolve prior to the most recent glacial periods. Tolerance to nickel is believed brought about by exclusion, such as a precipitate outside the root system and by the presence of increased levels of malic and malonic acids in the Brassicaceae. The authors believe these plants evolved in parallel from a small number of ancestors because they possess close morphological relationships. Four possible factors responsible for the restricted distribution of nickel accumulating endemics are: 1) specialized physiology which requires serpentine soils to grow (stated as not likely); 2) competition from other plants; 3) insufficient time since development to spread in range; 4) increased nickel in all plant parts, particularly leaves, may confer protection against fungal attack which is lost when plants germinate beyond a nickeliferous environment.

Reeves, D.R., R.R. Brooks, and R.M. MacFarlane. 1981. Nickel uptake by California Streptanthus and Caulanthus with particular reference to the hyperaccumulator S. polygaloides Gray (Brassicaceae). **American Journal of Botany** 68:708-712.

For this study the nickel content of herbarium specimens was analyzed. All serpentine species had elevated levels of nickel but S. polygaloides was found to be a hyperaccumulator (with nickel levels over 100 times that of any other Streptanthus and more than 3 times that of the soil). This taxon occurs in the Sierra Nevada foothills. Its physiology supports a recent monotypic reclassification to Microsemia polygaloides which has been proposed. It also has marked morphological differences from other member of Steptanthus. About half of the known nickel hyperaccumulators are in the Brassicaceae. Tolerance is believed to come about by uptake and complexing of the element within the plant. S. brachiatus was analyzed for this study and found to have moderate levels of nickel.

Reeves, D.R., R.M. MacFarlane, and R.R. Brooks. 1983. Accumulation of nickel and zinc by Western North American genera containing serpentine-tolerant species. **American Journal of Botany** 70:1297-1303.

Three varieties of Thlaspi montanum (Brassicaeae) were found to be hyperaccumulators of nickel. They are believed to be neoendemics rather than paleoendemics (relatively recent rather than ancient). Streptanthus polygaloides is the only other known nickel hyperaccumlator found in the continental United States. The precursor of these taxa is believed to be T. montanum var. montanum which grows on non-mineralized soils.

Rockwell International, Environmental Monitoring & Services Center, Environmental and Energy Services Division. 1980. Environmental baseline study plan for Shell leasehold CA-949-950. Submitted to U.S.G.S. Department of the Interior, U.S. Geothermal Supervisor, Palo Alto, California.

Previous reports have found members of the Streptanthus morrisonii complex in this area. To mitigate impacts, surveys of barrens areas and avoidance of any unusual, threatened, or endangered species are recommended.

Rodman, J.E., Kruckeberg, A.R., and I.A. Al-Shehbaz. 1981. Chemotaxonomic diversity and complexity in seed glucosinolates in Caulanthus and Streptanthus (Cruciferae). **Systematic Botany** 6:197-222.

Seed glucosinolate (mustard oil glucoside) profiles (kinds and proportions of constituents) from serpentine adapted taxa appear to be as chemically diverse and complex as non-serpentine taxa. Forty species of Streptanthus and Caulanthus were studied. For species with a lot of infraspecific variation, profiles correlated with morphologically recognized infraspecific taxa. Streptanthus morrisonii and S. brachiatus were collected for this study but no subspecies were designated. Both species had chemical profiles with high diversity and phenograms generated based on the chemical data showed a great distance between them.

Shapiro, A.M. 1981a. The pierid fauna of jewel flower at a mid-elevation Sierran locality. **Journal of the Lepidopterists' Society**. 35:322-324.

Study of Pierids on Streptanthus tortuosus, a wide-ranging species on many different soils. In the population studied, 12.3% of plants had some insect herbivore damage and 2.5% of the total reproductive potential of the population was lost. The author observed a great deal of damage in this and other populations but Kruckeberg is quoted from a personal correspondance as stating that he rarely observes insect predation on Streptanthus. Shapiro notes that, if larval survivorship is high, even plants receiving just one pierid egg will probably set no seed and that isolated individuals appear to be at greater risk than those in dense stands.

Shapiro. A.M. 1981b. The pierid red-egg syndrome. **American Naturalist** 117:276-294.

This paper contains a discussion of pierid-host plant evolution, specifically the production of egg mimics on the leaves of some species of Streptanthus. These colored callosities are believed to look like eggs to female pierids looking for plants on which to lay their eggs and they are prone to avoid plants which already have eggs present. These mimics are found only on serpentine races of Streptanthus where nutrients are presumed low and insect predation would be a grave threat to successful seed-set.

Shapiro, A.M. 1981c. Egg-mimics of Streptanthus (Cruciferae) deter oviposition by Pieris sisymbrii (Lepidoptera: Pieridae). **Oecologia** (Berl) 48:142-143.

Streptanthus breweri, a serpentine-soil annual mustard, produces pigmented callosities on its upper leaves which are thought to mimic the eggs of the Pierid butterfly Pieris sisymbrii. This is one of several inflorescence-infructescence-feeding Pierids which assess egg load visually on individual host plants prior to laying eggs (oviposition). Removal of the 'egg-mimics' from S. breweri plants in situ significantly increased the probability of an ovipositon relative to a similar, intact plant. Some plants used in this study were from Butts Canyon, near the KGRA, in Napa County.

Sjolund, R.D. and T.E. Weier. 1971. An ultrastructual study of chlorplast structure and dedifferentiation in tissue cultures of Streptanthus tortuosus (Cruciferae). **American Journal of Botany** 58:172-181.

This article is included to indicate that species of Streptanthus have been found to have useful properties for other types of scientific inquiry than solely ecological or evolutionary studies.

Stebbins, G.L. 1942. The genetic approach to problems of rare and endemic species. **Madrono** 6:241-258.

This paper contains a discussion of why some plants are widespread and common while others are rare and local. It may be that endemics are recently evolved taxa which have not had time to spread in distribution but fossil records and genetics discount this explanation in many cases. Fernald proposed that senescence was responsible; rare plants were once more common but great age has made them now unable to spread. The inability to spread, however, may have nothing to do with age. Most widespread and common species consist of a number of genetically different biotypes or ecotypes, many of which differ widely in their ecological preferences. This ecotype concept was fairly new at the time of this paper, based largely on the work of Tueresson, Clausen, Keck, and Hiesey. It leads to the conclusion that a species poor in biotypes or with extremely specialized biotyoes will be more restricted and rare. Inabilty to compete with other species may also be a factor; many rare species find their habitats in early successional ecological stages. This paper mentions Streptanthus and states that the serpentine areas where this genus usually occurs are essentially islands and that these species have probably always been rare and may have been

derived from a relatively recent wide-ranging species. The future of rare plants in general is predicted to be stable if the environments in which they occur are stable; being rare does not necessarily mean a plant is on its way to extinction.

Stebbins, G.L. and J. Major. 1965. Endemism and speciation in the California flora. **Ecological Monographs** 35:1-35.

This is a review paper which addresses endemism in the entire state. Northern Lake and southern Napa Counties from Calistoga and Mt. St. Helena to Clear Lake are identified as a local center of endemism in the central Coast Ranges for which there is no published flora.

Turitzin, S.N. 1981. Nutrient limitations to plant growth in a California serpentine grassland. **American Naturalist** 107:95-99.

This paper is a report on a study to try to improve grassland on serpentine soil. Results of addition of fertilizer showed low levels of nitrogen and phosphorus appear to be limiting growth. Potassium, sulphur, and calcium additions had little or no effect. The absence of an effect from addition of calcium shows low levels of this mineral is not a universal explantation for low primary productivity on serpentine as is sometimes stated in the literature.

U.S. Department of the Interior, Bureau of Land Management. 1978. Environmental Assessment for proposed geothermal leasing in the Geysers mineral reserve lands (Five Tract). Ukiah District Office.

Maps of plant communities and sensitive species are presented. There is a record of a collection of Streptanthus batrachopus (otherwise known only from Marin County) which is noted to need further identification. Members of the S. morrisonii complex are listed as occurring near the study area.

U.S. Department of the Interior, Bureau of Land Management. 1980. Geyser Peak Mineral Reserve proposed geothermal leasing Draft Environmental Assessment. Ukiah District Office.

This report has descriptions of the plant communities present. Streptanthus brachiatus and S. morrisonii ssp. elatus are listed as species which may occur on the study site. For mitigation of impacts this report suggests that, in general, disturbances to barrens areas should be avoided. These areas have the highest probability of any areas in the study site to contain sensitive species.

U.S. Department of the Interior, Bureau of Land Management. 1981. Environmental Assessment, Kelsey Creek proposed geothermal leasing. Ukiah District Office.

Maps of soil types and plant communities, including serpentine chaparral are included. Quercus durata, Cupressus sargentii, and Ceonothus jepsonii are considered indicator species for this community. Streptanthus plants were found during the field surveys for this report but could not be identified to species due to the time of year.

U.S. Department of the Interior, Bureau of Land Management. 1987. Draft Knoxville ORV Management Plan. Clear Lake Resource Area, Ukiah District Office.

The area covered by this management plan includes the entire known range of an apparently undescribed member of the **Streptanthus morrisonii** complex. Field work was conducted by Tierra Madre Consultants. Maps of all barrens habitat are included along with population size estimates. The Plan provides for the preservation of barrens by allowing only non-motorized activity in these areas.

Wallace, A, M.B. Jones, and G.V. Alexander. 1982. Mineral composition of native woody plants growing on a serpentine soil in California. **Soil Science** 134:42-49.

Using optical emission spectrography, leaves of five native plant species collected in northern California (Adenostoma fasciculatum, Arctostaphylos viscida, Cupressus macnabiana, Cupressus sargentii, and Quercus durata) and analyzed for mineral elements. In these plants, which are reasonably adapted to serpentine soil conditions, the calcium/magnesium ratios were normal in contrast to plants not adapted to such soil conditions. The nickel concentrations in the leaves were low for serpentine soil conditions, and there was no tendency for accumulation of chromium or cobalt.

Walker, R.B. 1954. The ecology of serpentine soils. II. Factors affecting plant growth on serpentine soils. **Ecology** 35:260-266.

This paper presents a description of the physical and chemical properties of serpentine soils and the vegetation found on them. The importance of the following factors in determining plant tolerance to serpentine soils was examined: 1) low levels of major nutrients, especially nitrogen and phosphorus; 2) alkalinity; 3) low levels of available molybdenum; 4) toxicity of nickel or chromium; 5) status of calcium and magnesium in the soil; and 6) shallow soil depths. Experimental evidence favors the view that low calcium levels and one or more of the above are the key factors influencing tolerance.

Whittaker, R.H. 1954a. The ecology of serpentine soils. I. Introduction. **Ecology** 35:258-259.

Introduction for three papers on serpentine soils and plant ecology. Serpentine soils are found all over the world (Sweden, Great Britain, Austria, the Ural Mountains, Rhodesia, Japan, New Zealand, Indonesia, Cuba, Puerto Rico, Canada, and other locations). In the United States serpentine soils are found in Massachusetts, Maryland, and scattered along the Appalachian chain south to Georgia but the Pacific Coast has the most extensive regions. These numerous serpentine areas have some features in common: 1) sterile and unproductive either as farm land or timber land; 2) possess unusual floras characterized by narrow endemics; 3) support vegetation in striking physiognomic contrast to that of other surrounding soils.

Whittaker, R.H. 1954b. The ecology of serpentine soils. IV. The vegetational response to serpentine soils. **Ecology** 35:275-288.

A comparative vegetation study at low elevations on serpentine and quartz diorite in the Siskiyou Mountains of southwestern Oregon. This serpentine flora is climax, although it is affected by fire. It is characterized by xeromorphism resulting from a basic reduction of productivity and structure toward the lower strata and dominance of conifers (especially pines), sclerophyllous shrubs, and grasses.

Woodell, S.R.J., H.A. Mooney, and H. Lewis. 1975. The adaptation to serpentine soil in California of the annual species Linanthus androsaceus (Polemoniaceae). **Bulletin of the Torrey Botanical Club** 102:232-238.

The ability of serpentine adapted plants of L. androsaceus to flourish on serpentine soils, in contrast to the inability of non-serpentine plants to do so, is apparently the result of several factors. Prominent among these are the calcium/magnesium ratio and nickel and chromium toxicity.